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GROUND-WATER CONTAMINATION:
Problems and Remedial Actions

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ABSTRACT

Case histories of 116 ground-water contamination incidents reveal that remedial action is usually complex, time consuming, and expensive. Quick recognition of and response to an emergency involving ground water are essential to minimize the spread of contamination and make only minor remedial action necessary. However, the hydrogeologic setting and the pollution hazard at the specific locality should be assessed before corrective action is taken.

The remedies most frequently used to renovate the subsurface environment include pumping and treating ground water, removing soil, draining away ground water via trenches, and removing the source of contamination. A combination of these techniques also has been used.

Existing emergency strategies, however, are designed for coping with spills affecting surface water. No formal programs have been developed for dealing specifically with contamination of land or ground water. Each incident has been handled as a separate problem.

In Illinois, many resources are available for handling emergency pollution problems, but they are scattered among a number of state agencies. Suggested here are guidelines for strategies that consider both the administrative structure of Illinois and the hydrogeologic framework of the state. To define the scope of the problem and develop a formal procedure for dealing with various kinds of land and ground-water pollution emergencies, creation of a committee or task force is suggested.

Guidelines for strategies that consider the hydrogeologic framework and administrative structure of Illinois are presented. A committee or task force should define the scope of the problem and develop a formal procedure for dealing with various kinds of land and ground-water pollution emergencies.

INTRODUCTION

Regulatory agencies are increasingly faced with the problem of how emergency incidents of ground-water pollution can be effectively handled. The emergency may be the result of an accidental spill on the ground or the discovery of contamination in a water well. If the release of contaminants to the ground is detected quickly, remedial action can be taken to limit the spread of contamination and to simplify recovery. In most cases, however, the problem is not immediately recognized. A contaminant often seeps into the ground undetected, moves through the earth material to the water table, then moves with the ground-water flow system. Contamination of a water well is often the first indication that a problem exists.

Contamination of water is defined in Webster's Third International Dictionary as the alteration of its quality in an undesirable manner. Continued build-up of contaminants in water results in pollution, which renders the water unfit for a particular use.

Generally, the longer it takes to discover contamination in the subsurface, the larger the zone of contamination is likely to be and the more likely the possibility that ground water will become polluted. Clean-up operations will probably also prove more expensive and difficult.

The variety of geologic settings and possible contaminants makes the preparation of plans or strategies for dealing with ground-water emergencies difficult. Perhaps it is not surprising that a survey of state evironmental agencies revealed no strategies for dealing with such emergencies. Yet the number of reported incidents is likely to increase in the future, partly because of the increased surveillance by environmental regulatory agencies and the spreading awareness of problems on the part of the general public.

In Illinois, the Environmental Protection Act of 1970 (HB 3788) provides more comprehensive regulation than had existed previously by combining the activities of several organizations into one agency—the Illinois Environmental Protection Agency (IEPA). The agency enforces regulations designed to protect the physical environment and public health.

Disposal of wastes on or in the land is likely to increase as such disposal is increasingly forbidden in surface waters. In 1972 amendments to the Federal Water Pollution Control Act set as a national goal the elimination of disposal of contaminants into navigable waters by 1985. As required treatment of wastes to be discharged to surface waters becomes more stringent and more expensive, an increasing number of industries will look to land disposal as a cheaper alternative. The result is liable to be more ground-water contamination. In addition, the contaminants removed during treatment of wastes will be deposited in a land disposal site if they cannot be recycled.

Because of the need for strategies to handle incidents of subsurface contamination effectively, the Illinois State Geological Survey undertook a study for the Illinois Institute for Environmental Quality to determine what strategies were in use elsewhere that might be adopted in Illinois. The study is a natural outgrowth of research carried on at the Geological Survey for the

past several years. The Survey has been studying movement of contaminants within the hydrogeologic framework, and it has advised several local and state authorities during emergencies involving ground-water pollution.

First, we reviewed the literature for documented cases of ground-water contamination or pollution to learn what strategies had been used elsewhere in emergency situations. The incidents were evaluated in the context of their hydrogeologic setting. The case studies are summarized in the Appendix of this report.

Second, we asked appropriate environmental agencies in the other 49 states and several Canadian provinces what strategies, if any, they had developed for dealing with emergency ground-water pollution problems.

Third, Survey personnel discussed ground-water contamination problems with state officials in Illinois. Information was obtained about current policies of the IEPA and about the expertise and resources available in the state for dealing with emergency ground-water pollution problems.

Fourth, we developed guidelines for strategies that consider the hydrogeologic framework and administrative structure of Illinois. The guidelines were formulated on the basis of information gathered in this study and from the files of the Geological Survey.

This publication is basically the final report that was submitted to the Illinois Institute for Environmental Quality.

GROUND-WATER CONTAMINATION AND THE SUBSURFACE ENVIRONMENT

Occurrence and Movement of Ground Water

Before strategies for dealing with ground-water pollution emergencies can be developed, the movement of ground water and contaminants in the subsurface environment must be understood. Ground water is derived primarily from rainfall. A portion of the rainfall infiltrates downward through the soil's zone of aeration (fig. 1), where voids in the earth material contain air or water. Some water may be held in the zone of aeration by the attractive forces between water and soil particles. Water in excess of the amount held by these attractive forces moves downward in response to gravity to the zone of saturation, in which all the openings are water-filled. The upper surface of the zone of saturation is called the water table.

Saturated earth materials that yield water to wells and springs are called aquifers (fig. 1). An aquifer may be either unconfined (that is, contain water under atmospheric pressure) or confined (contain water under greater than atmospheric pressure). A confined (artesian) aquifer is overlain by an aquiclude—material that is less permeable than the aquifer and restricts vertical movement of the water (fig. 1). A local zone of saturation may be held above the regional water table by a local aquiclude. The local water table is then said to be perched. This condition is not common in Illinois.

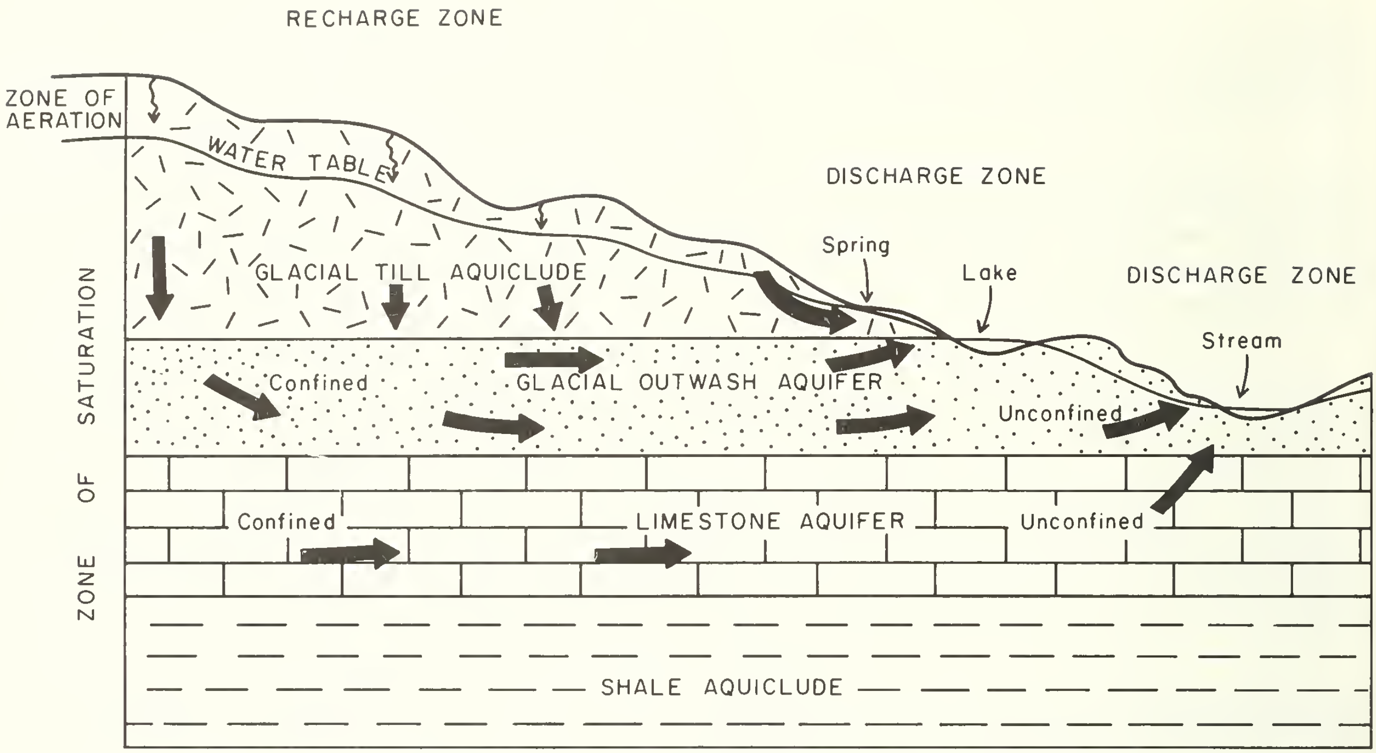

Fig. 1 - Ground-water movement within hypothetical flow system.

The rate of movement of subsurface water is influenced by the size of the voids in the earth materials and the degree to which these openings are interconnected. Permeability is the capacity of earth materials to transmit liquids. Hydraulic conductivity (often incorrectly used as a synonym for permeability) is a property of the earth material and water and indicates the ability of the earth material to conduct water (Bear, 1972, p. 7). Sands and gravels generally have high hydraulic conductivities because the openings are large and well connected. Silts and clays, with small openings, have low hydraulic conductivities. Bedrock composed of granular materials may have either high or low hydraulic conductivities, depending on grain size and degree of cementation. Bedrock that is jointed or fractured permits water to move rapidly along the joint or fracture openings so that hydraulic conductivities in such rock tend to be high. Rates of ground-water movement can be a few to tens of feet per day or only a few to tens of feet per year.

Ground water moves in response to gravity from the area of infiltration (recharge) to a place of discharge, where the water table intersects the land surface (fig. 1). Recharge areas are often topographic highs and discharge areas are typically topographic lows. The water table commonly is a subdued reflection of the land surface.

Ideally, if earth materials were homogeneous, the prediction of ground-water movement would be fairly simple. In reality, earth materials vary both vertically and laterally. Glacial deposits, for example, can vary even within a few feet, thus altering the direction of ground-water movement. The movement of ground water in fractured or jointed bedrock is also difficult to predict without detailed information about the subsurface.

The ground-water flow pattern may also be affected near pumping wells. The water table is drawn down near the well, creating a cone of depression that surrounds the well. The water-table gradient is quite steep in the cone of depression, causing rapid movement of ground water to the well. Pumping may even reverse the natural direction of ground-water flow.

Transport and Attenuation of Contaminants in Ground Water

Several factors influence the transport and attenuation of contaminants in water in the subsurface environment. Among the most important factors are the texture and composition of the earth materials. Fine-grained deposits filter out bacteria and reduce concentrations of some chemical constituents by ion exchange. Clay minerals in particular have the capacity of exchanging ions with contaminants in ground water, thereby immobilizing certain contaminant ions and reducing their concentrations in solution. In general, cations such as cadmium, lead, zinc, copper, mercury, and trivalent chromium tend to be adsorbed by clay minerals, whereas arsenic, selenium, chloride, nitrate, and hexavalent chromium are among the ions only weakly adsorbed (Griffin et al., 1976, 1977). The amount of exchange a particular cation undergoes is a function of (1) the clay minerals involved, (2) the cations already on the clay, (3) the other cations in solution, and (4) the accompanying anions.

Silts and sands are also able to exchange ions to a limited degree. Sand and gravel and fractured bedrock aquifers generally afford little or no attenuation of either chemical or bacteriological contaminants.

Another important factor is the nature of the contaminant itself. Some chemical contaminants may be at least partially removed through ion exchange with the earth materials, as mentioned above. Some pollutants may break down naturally in the subsurface environment. Petroleum products, for example, may be broken down by bacteria. However, the absence of oxygen below the water table limits the effectiveness of this process, and a long interval may be necessary for complete breakdown of petroleum products.

In addition, contaminants such as petroleum products are lighter than water and float on the water table. Very little mixing with ground water may take place. Oil-field brines, on the other hand, are typically denser than natural ground water. Brine may mix to a certain extent with ground water or may sink toward the base of the aquifer.

Other controls on contamination are the volume of contaminant and the rate at which it reaches the ground-water flow system. If a large volume of contaminant is introduced to the ground-water system within a fairly short time, a ground-water mound may form at the place the contaminant entered. The mound may alter the direction of ground-water movement and make remedial action more difficult. Ground-water mounds are often found beneath landfills as a result of high infiltration and the formation of leachate.

The position of the source of contamination within the flow system is another important factor in determining the extent of contamination. In

most circumstances, the zone most affected is the shallow, unconfined aquifer near the surface. Deeper aquifers are often unaffected. However, if the contamination originates in an upland recharge area, a large portion of an aquifer may be contaminated. The closer the contamination occurs to the discharge zone, the smaller the potential area of ground-water contamination will be (fig. 2). However, surface-water contamination could be a more serious problem.

Surface-water flow is often turbulent, and dilution and dispersion are effective mechanisms for reducing concentrations of contaminants in surface waters. In contrast, ground-water flow is laminar, in smooth parallel lines. As a result, dilution and dispersion are slow and ineffective processes for renovation of subsurface contamination.

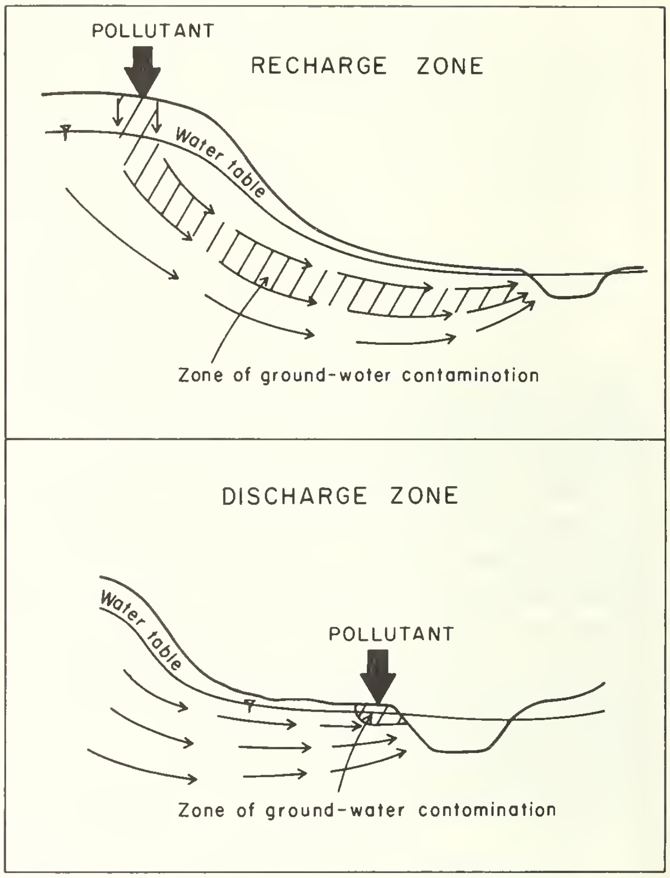

Fig. 2 - Extent of ground-water contamination from pollutant entering recharge and discharge zones (after Bergstrom, 1968).

LESSONS FROM CASE HISTORIES

In the cases of pollution studied, information was sought on the location, source of contamination, effect on the environment, background, geologic setting, and remedial action and its effectiveness. Case histories were obtained from published reports, information submitted by agencies from several states and provinces, and personal experience. The 116 case histories included here were summarized and appear as Appendix A. Other ground-water contamination incidents are mentioned in the literature, but they were not described in sufficient detail to warrant inclusion in this report.

The information derived from the 116 case histories is summarized in table 1, which lists the contaminant, how the emergency was detected, and the remedial action taken. As the ground-water clean-up operation often involved several steps, the total number of remedial actions is considerably higher than 116. Table 1 gives 118 sources of contamination because, in two cases, more than one source was detected.

The information presented in the case histories found in the literature varied considerably, partly because the articles were written for many different purposes. Some were written to summarize a pollution emergency and the remedial action taken, others to give the results of a study that proved the presence of ground-water contamination (although generally no mention of remedial action was made), still others to discuss techniques for defining the extent of ground-water contamination.

TABLE 1—SUMMARY OF INFORMATION FROM DOCUMENTED CASE HISTORIES

Contaminant	Total	Cases affecting or threatening water supplies	Cases causing or threatening fire or explosion
Industrial wastes	40	26	2
Landfill leachate	32	7	0
Petroleum products	18	10	8
Chlorides (road salt and oil field brine)	11	9	0
Organic wastes	11	9	0
Pesticides	3	2	0
Radioactive wastes	1	0	0
Mine wastes	2	1	0
	118	64	10

Means of Detection

Well contamination	58	Not mentioned	4
Investigation	32	Fumes in basement	1
Stream contamination	9	Fumes in ground	1
Spill on ground	5	Fumes in sewer line	1
Leak discovered	4	Animal deaths	1

Total 116

Remedial Action

Direct		Indirect	
Ground water pumped and treated	27	Extent of ground-water contamination determined	44
Contaminated soil removed	8	Leading to remedial action	25
Trench installed	8	No further action	19
Artificial recharge employed	4	New water supply provided	16
Nutrients added	2	Action being considered	9
Source of contamination eliminated	26	Monitoring begun	2
Surface water collected and treated	7	Damages awarded	4
Landfill site closed	9	Charcoal filters installed	2
Site regraded	3	None mentioned	12
	94		89

Although most ground-water contamination incidents are poorly described in the literature, some case histories have been well documented, and they provide a useful base of information for developing effective strategies for land or ground-water emergencies. The following discussion summarizes the information derived from the case studies as it pertains to this report.

Factors Affecting Remedial Action

A common theme of the case histories is that remedial action following a land or ground-water emergency is a time-consuming and expensive process. The corrective action necessary to renovate ground water effectively following an emergency is complicated for several reasons.

Spills of contaminants into surface water are readily apparent and quick action can be taken. Even spills on land, if recognized soon enough, may be contained and remedial action minimized. Unfortunately, less than 10 percent of the documented cases developed as spills, and most of these cases were either so severe or the response was delayed so long that corrective action was difficult. In most cases, contamination was not discovered until some time after the contaminant had entered the ground, because once a contaminant enters the subsurface it is out of sight, perhaps leaving no surficial evidence of subsurface contamination. As a result, the contaminant may travel a great distance and affect a large portion of an aquifer before pollution is recognized. Weeks, months, or even years may elapse before a ground-water pollution problem is discovered. In one case, industrial wastes were discharged to unlined lagoons for about 11 years before ground-water pollution was detected. By that time, several square miles of the shallow aquifer had been affected (Walton, 1961; T. Walker, 1961). In another case, a well in Minnesota became polluted shortly after installation in 1972. Only after an exhaustive investigation was it learned that the site had been used in the mid-1930s for disposal of a grasshopper pesticide that contained arsenic (U.S. EPA, 1975).

The contaminant may be discovered as it discharges with ground water to a local body of surface water. More often, however, the contaminant appears in a well. Half the problems documented in this report (58 of 116) were first detected as a result of well pollution. In many cases, water supplies are affected or threatened. One such incident occurred at the Llangollen landfill in northern Delaware. When a private well was found to be polluted as a result of the near-by landfill operation, investigation revealed that a major portion of a widely used shallow aquifer was affected. Both industrial and public water supply wells are threatened by such contamination (Apgar and Satterthwaite, 1975; Garland and Mosher, 1975). In another incident, gasoline from an unknown source affected a municipal well and a number of private wells (Wikre, 1973, p. 76-77).

Because subsurface contamination is not visible, there is normally no simple way to determine the extent of ground-water contamination. Wells in an affected area may be useful indicators, but in most cases there are too few wells to permit delineation of the extent of the pollution. It is, therefore, often necessary to drill wells or borings in an area to define the zone

of contamination. As the result of a gasoline pollution problem in the Los Angeles area in the late 1960s, about 70 wells were drilled to determine the area affected and to pump out the gasoline (Williams and Wilder, 1971; American Petroleum Institute, 1972, p. 33-35). At the Llangollen landfill about 100 wells or borings have been made to date.

Finding the source of ground-water contamination, which is not always as readily apparent as it is for spills into surface waters, is a major problem. Contaminants may undergo changes in the subsurface environment that make them hard to identify. Petroleum products, for example, tend to break down in the subsurface, making correlation with suspected sources difficult. This was true in several of the cases studied.

Ground-water renovation is further complicated by the fact that not all contaminants behave in the same way in the subsurface environment. The type of remedial action taken is therefore dependent on the character of the contaminant. While some chemical constituents are adsorbed and attenuated in moving through the soil, others pass through with little or no attenuation. Chlorides and nitrates are not normally tied up by the soil and are therefore the contaminants most frequently detected. In Peoria, Illinois, an investigation was begun after high concentrations of chlorides were detected in an industrial well field. The main source of the chlorides was a near-by salt-storage area (W. H. Walker, 1968). Nitrate contamination of a private well was detected in a routine check of farm wells in Washington County, Illinois (Walker, Peck, and Lembke, 1972). The nitrates appeared to be coming from a septic system, an old hog lot, and agricultural fertilizer.

Petroleum products in particular show a tendency to become adsorbed by soil particles in the unsaturated zone. At least part of the oil thus becomes immobilized and is removed by continuous flushing. Complete recovery is, in this case, extremely difficult, for it may take years to flush out all the oil. A fuel-oil leak was discovered in Pennsylvania in 1967. Efforts have been made for 8 years to remove the fuel oil from the ground (Pennsylvania Department of Environmental Resources files), but precipitation continues to flush fuel oil to the water table and to a near-by stream.

Behavior of contaminants in the ground-water system depends on differences in density between the contaminant and the native ground water. In Mechanicsburg, Pennsylvania, as much as 4 feet of gasoline was found floating on top of the water table (Rhindress, 1971a, b). As a result of an incident in southeastern Pennsylvania, up to 5 feet of fuel oil was found on the water table (Emrich and Peterson, 1972). Other contaminants, however, may affect the entire thickness of an aquifer or a portion thereof. A study made in southeastern New Mexico to determine the extent of ground-water contamination by oil-field brines determined that chloride concentrations increased with depth because salt water is denser than the native ground water (McMillion, 1971).

Some incidents of ground-water contamination are more serious than others and, therefore, may require special attention. The more serious emergency situations are those that pollute or threaten water supplies and those that cause fires or explosions.

Most (64 of 116) of the documented case histories are of incidents where water supplies were affected or threatened. The contaminants included sewage, chlorides, petroleum products, and various types of industrial and hazardous wastes. For example, numerous New Jersey wells within a 1-mile radius were contaminated as a result of the illegal dumping of drums containing petrochemicals (Frank Markewicz, N. J. Department of Environmental Protection, personal communication, 1975).

People have become ill from drinking contaminated water. In Posen, Michigan, an outbreak of infectious hepatitis in 1959 was traced to wells located near septic systems and to improperly constructed wells (Vogt, 1961). In Perham, Minnesota, several people became sick from drinking well water that contained arsenic (U.S. EPA, 1975).

Petroleum products and some chemicals pose threats of fire or explosion. In 1968, a train containing hazardous chemicals was involved in an accident, resulting in an explosion, a fire, and spillage of chemicals (Dawson, Shuckrow, and Swift, 1970; Moore and Kin, 1969). In Rockaway Beach, New York, it was necessary to excavate a city block to remove spilled gasoline and prevent an explosion (Geraghty, 1962).

The threat of an explosion is particularly strong where explosive fumes are concentrated in confined areas. Gasoline fumes from a spill may collect in a basement, sewer line, or other subsurface excavation in explosive quantities, as occurred in a case involving gasoline at Spring Mill, Pennsylvania (Gold, Parizek, and Giddings, 1970), and Mechanicsburg, Pennsylvania (Rhindress, 1971a, b).

Refuse decomposition in a landfill produces leachate and methane gas, which also is explosive in confined quarters. The Illinois Geological Survey files indicate that at least one building has exploded as a result of the generation and accummulation of methane at a landfill in Elmhurst. The appearance of methane in several wells and some basements in Rockford was the first indication of contamination from a near-by landfill. There were no explosions, but the threat existed (Illinois State Geological Survey files).

It is apparent that some contaminants pose more of a threat in the subsurface environment than others. Petroleum products are flammable and become explosive as vapors; they must, therefore, be considered the most potentially dangerous contaminant. Although less than 20 percent of the case studies involved petroleum products, they were responsible for 80 percent of the incidents of contamination that caused or threatened explosions and/or fire. Certain toxic and/or explosive chemicals also can create dangerous conditions if not handled properly. Radioactive wastes also fall in this category. An open-file report by Rauf Piskin of the Illinois Environmental Protection Agency (1975) defines hazardous wastes as, "Any solid, semi-solid, liquid, or gaseous waste that is, by itself or in combination with other wastes, hazardous or potentially hazardous to human health and/or damaging to the environment, which requires special handling due to its toxic, flammable, explosive, pathological, or radioactive properties."

Other contaminants discussed in the case studies are considered dangerous only as they may affect water supplies, leachate from landfills, for example. In most cases in which water supplies have been affected by landfill leachate, the extent of contamination has been fairly limited. Less than 25 percent of the landfills noted in documented cases affected or threatened water supplies.

The case studies show that some waste substances pose a health hazard as a result of their being ingested in harmful quantities without detection. Some organic wastes, including bacteria, fall into this category. The outbreak of infectious hepatitis in Michigan caused by sewage is a case in point (Vogt, 1961). Most waste substances, however, are immediately apparent in water and would not be consumed.

Effectiveness of Remedial Action

A question raised in some case studies is whether remedial action is necessary or feasible. Several incidents were documented in which no corrective action was taken to remove the contaminants from the soil or ground water. In 19 cases, no remedial action was taken beyond determining the extent of contamination (table 1). One reason for ignoring the problem is the cost and time involved in such a venture. The discovery of salt water contamination in an aquifer in Arkansas stimulated a discussion of several ways of renovating the ground water, but all were rejected because of the expense (Fryberger, 1975). In New Jersey, consideration was given to pumping and treating ground water to purge an extensively polluted aquifer, but this proposal also was rejected because of cost and time (Frank Markewicz, N. J. Department of Environmental Protection, personal communication, 1975).

In other cases, no remedial action was taken because the source was not positively identified. This was true in several cases involving petroleum products. In Minnesota, for instance, gasoline was detected in a number of wells but the source of pollution was never found and no corrective action was taken (Wikre, 1973, p. 76-77).

Although not explicitly stating it, many case studies implied that no corrective action was taken because the contamination was not extensive. Rousch, LaFornara, and Nadeau (1974) discussed a truck spill of 5000 gallons of formaldehyde solution. Apparently because the extent of contamination was limited, no remedial action was taken. When insecticide contamination of a well in southeastern Pennsylvania prompted monitoring of near-by wells, only one well proved to be affected, and no effort to renovate ground water was made (Pennsylvania Department of Environmental Resources files).

In many cases only indirect remedial action was taken—that is, the action made the situation more tolerable to those affected but was not directed at improving the quality of ground water. The most frequent indirect response to well contamination was to provide a new water supply to those affected (table 1). For instance in Rockford, Illinois, several private wells, indus-

trial wells, and a public water supply well were contaminated by a near-by landfill operation. The homes with affected water supplies were provided with water from other wells of the city water system (Illinois Environmental Protection Agency files).

Damages have been awarded in some instances to persons whose wells have been polluted. In Aurora, Illinois, a judge awarded $88,000 to seven persons whose wells were found to contain leachate from a near-by landfill (Illinois Environmental Protection Agency files).

Two direct approaches (table 1) have been taken to try to renovate contaminated ground water and subsoil. One approach is to attempt recovery of the contaminants from the soil or ground water. The second is to eliminate the source of contamination and rely on natural recharge and flushing action to remove the contaminants from the subsurface, thereby improving water quality.

Direct remedial action is complicated by the fact that hydrogeologic conditions vary from one place to another. The techniques used to recover contaminants will depend on the geologic setting at the particular site. Techniques that work in one geologic setting may not work in another.

Pumping a well to recover contaminants was found to be most effective in sites underlain by permeable rock materials such as coarse-grained deposits and fractured or jointed rocks. Chloride concentrations in a sand aquifer were reduced significantly by pumping for a period of over 20 months (McMillion, 1971). Pumping and treatment of ground water were used effectively in Mapleton, Illinois, in 1973 to renovate ground water after a train derailment that spilled 20,000 gallons of vinyl cyanide (Illinois Environmental Protection Agency files).

Movement of pollutants along fractures or joints in bedrock presents special problems. Hydraulic conductivities along these openings are high, and contaminants may spread rapidly along the fractures. Therefore, the fracture patterns must be known before the extent of pollution can be gauged and a program of remedial action prepared. As a case in point, a gasoline pipeline break resulted in widespread contamination of a fractured limestone aquifer in southeastern Pennsylvania. Fracture-trace analysis was used extensively to locate new wells for recovery of the gasoline (Gillies, 1974).

By contrast, contaminants move slowly in fine-grained materials, making successful recovery of contaminants by ground-water pumping less likely. In Charleston, Illinois, a train derailment in 1969 spilled about 15,000 gallons of cyanide. The presence of a 12-foot clay zone beneath the soil limited the environmental damage, though the low permeability also limited the effectiveness of the pumping and artificial recharge that were used to remove the contaminants. A large volume of contaminated soil was finally removed and treated to recover the bulk of the cyanide (Illinois Environmental Protection Agency files).

Ground-water pumping has generally worked well for incidents involving petroleum products. Ground water was pumped extensively in central Pennsylvania following a major case of gasoline contamination. More than 40 wells

were drilled, and about 216,000 gallons of gasoline were recovered (Rhindress, 1971a, b), probably most of the gasoline that was lost; however, the total volume of gasoline lost could not be determined because the source was never identified.

The cases involving petroleum products suggest that there is a limit to the effectiveness of pumping to recover the contaminant. Pumping may remove the petroleum that floats free on top of the water table, but some of the petroleum remains attached to soil or rock and is only slowly flushed out. In a recovery program in Savannah, Georgia, where an estimated 50,000 gallons of gasoline had seeped into the subsurface, only 5000 gallons had been recovered when the case was closed (American Petroleum Institute, 1972, p. 35-36). No techniques have been developed to remove the remaining petroleum products effectively. In southeastern Pennsylvania nutrients in the form of phosphates and nitrates were used to feed gasoline-degrading bacteria in ground water after recovery of gasoline by pumping dropped off. An additional 30,000 gallons of gasoline were recovered. However, an estimated 30,000 gallons of gasoline still remain in the subsurface (Gillies, 1974).

Artificial recharge has been used effectively in conjunction with pumping to increase the flushing of contaminants to a recovery well, especially where the earth materials are permeable. The combination was used to remove chlorides successfully from a gravel aquifer in Ohio (Parks, 1959).

Where the water table is at a shallow depth, a trench often proved useful in collecting the contaminants. This technique may be especially valuable for incidents involving petroleum products that float on the water table. A case discussed by the American Petroleum Institute (1972, p. 32) illustrates this point. An unknown quantity of heating oil was lost over several months before the source of the leak was discovered. Because the water table was at a depth of only 5 feet, a collection ditch proved effective in collecting the oil. In addition to being well suited to petroleum recovery, trenches installed along the perimeters of landfills also have been effective in collecting leachate (Andersen and Dornbush, 1972, Fosse, 1972).

Another technique used effectively in several cases was the removal of contaminated soil. In cases in which the extent of contamination was small, it was the only remedial action taken. In 1972, for example, an unknown volume of industrial waste (xylene) was dumped into a drainage ditch, contaminating the soil and a near-by stream. The affected soil was removed within a few days, apparently preventing further environmental damage (Pennsylvania Department of Environmental Resources files). In other situations removal has been used effectively in conjunction with pumping to improve ground-water quality.

Elimination of the source of contamination and reliance on natural flushing action to improve water quality is a strategy obviously slower than recovering the contaminants and is often less effective. W. H. Walker (1969, p. 36) reported on a gasoline pipeline break at Creve Coeur, Illinois. Although the break was repaired within a few hours, no other action was taken and gasoline persisted in the ground water for at least 4 years.

Well pollution in Ledyard, Connecticut, was traced to improper disposal of barrels of styrene, an aromatic hydrocarbon. The barrels were removed

but no further action was taken, yet within 2 years the wells no longer showed any styrene (Grossman, 1970). In another case, a salt pile was implicated as a source of local well contamination in Indianapolis, Indiana. Removal of the salt pile resulted in a gradual drop in chloride levels in near-by wells without further remedy (Dennis, 1973).

In several cases, surface water was collected and treated as part of the remedial action. A truck accident near Cumberland, Maryland, in 1972 spilled 25,000 gallons of phenol. Surface water runoff was collected and treated to minimize phenol infiltration into the soil (Ramsey and MacCrum, 1974).

Some case studies indicate that action was taken before sufficient information was obtained for planning a proper remedial program. At Rockford, Illinois, well contamination was initially detected in an industrial well near a landfill. Use of the well was ordered discontinued, which permitted the contaminants to migrate past that well to other wells in the area, including a municipal supply well and several private wells. These wells then had to be abandoned (Illinois State Geological Survey files). Perhaps an early technical evaluation in response to the initial well contamination would have resulted in successful remedial action to minimize further ground-water contamination. At Geneseo, Illinois, the city landfill was closed when it was noticed that the water quality in a near-by municipal well field had deteriorated. However, there has been no conclusive technical evidence that the landfill was responsible for the deterioration, even though the geologic setting is undesirable for landfill operations, and the closing may not have been necessary (Illinois State Geological Survey files).

Conclusions from Case Histories

To summarize, case histories indicate that remedial action for ground-water and earth contamination is usually complex, time consuming, and expensive. Because subsurface movement of ground water and contaminants is not visible, contaminants may move a great distance and adversely affect a large portion of an aquifer before they are detected. The source of contamination may not be readily apparent.

Some incidents are more serious than others and may require special attention. The more serious emergency situations are those that pollute or threaten water supplies and those that cause fire or explosions.

Quick recognition and response to an emergency involving ground water is important so that the spread of contamination can be held to a minimum. An appraisal of the geologic and hydrogeologic setting must be made and the pollution hazard for a specific incident evaluated before a plan of corrective action can be developed. The remedial actions most frequently used to renovate the subsurface environment include pumping and treating ground water, removing soil, draining ground water by means of trenches, and removing the source of contamination. A combination of techniques has also been used.

HOW OTHER STATES MEET EMERGENCIES

To learn what other states are doing regarding ground-water pollution problems, letters were sent to environmental protection agencies in the other 49 states and nine Canadian provinces. The letters requested information on plans that may have been developed to deal with ground-water emergency situations and documented case histories of ground-water pollution. Responses were received from 27 states and six provinces. The responses varied widely, making it difficult to compare emergency programs from one state to another. However, state emergency programs generally fall into one or more of four categories (table 2):

1. A formal, written plan has been developed for responding to pollution emergencies. The plans are designed for coping with surface-water contamination and generally spell out the responsibilities of state personnel and the resources available for handling surface-water contamination. No specific written plans have been developed for ground-water emergencies.

2. An informal plan has been prepared for responding to and evaluating surface-water and/or ground-water pollution incidents. The programs of this category are less detailed than those of category 1, in general being limited to an outline of steps to be taken for an early evaluation of the emergency.

3. No ground-water pollution strategy has been developed. Each emergency is handled on an individual basis.

4. The agency has no jurisdiction over ground-water pollution problems.

Several conclusions can be drawn from the letters received. Twelve states have either a formal or informal plan for action in the event of a pollution emergency. However, the emphasis is on spills affecting surface water. The role of the state agency is to investigate, give advice regarding clean-up, and enforce laws to insure proper clean-up. In some cases, a network of state agencies may become involved in offering advice or assistance, especially if the source can be identified.

The most significant conclusion drawn from the responses as it affects this study is that no formal strategies have been developed specifically for ground-water pollution emergencies. Most of the states that responded indicated some experience with ground-water pollution problems but had no specific plans or strategies for dealing with them. Incidents are usually handled on a case by case basis. Rhode Island has no jurisdiction over ground-water pollution problems.

The closest approach to a strategy for dealing with such emergencies is the ground-water protection program of the Pennsylvania Department of Environmental Resources (DER). This program was described in some detail by

TABLE 2—SUMMARY OF RESPONSES TO SURVEY OF PROGRAMS USED IN LAND AND GROUND-WATER POLLUTION EMERGENCIES

State or province	Category of emergency program	Experience with ground-water pollution emergencies	Comments
Arizona	1,3	—	
California	1	—	
Connecticut	2, 3	X	
Delaware	3	X	Legal authority available to insure proper clean-up
Florida	3	—	
Idaho	3	—	
Illinois	1, 3	X	
Kansas	3	X	
Maine	3	X	
Maryland	3	X	
Massachusetts	3	X	
Minnesota	3	X	Those responsible for spills must report and clean up
Mississippi	3	—	
Missouri	3	—	
Nebraska	1	X	
New Jersey	3	X	
New York	1	—	
North Carolina	2	X	
North Dakota	1, 3	X	
Ohio	3	X	
Oregon	2	X	
Pennsylvania	2	X	Informal strategy for ground-water pollution cases
Rhode Island	4	—	Ground water not considered as "waters of the state"
South Dakota	2	—	
Tennessee	3	—	
Vermont	3	X	
Washington	1, 3	—	
British Columbia	1	—	
Manitoba	2, 3	X	Legal authority to require pollution clean-up
New Brunswick	2, 3	—	
Ontario	1	—	
Prince Edward Island	3	X	
Saskatchewan	3	X	

Gillies (1974). In the event of a spill or other accident involving or threatening ground-water contamination, a geologist from the DER attempts to make an evaluation at the site as quickly as possible. If the environmental damage is slight, the DER may direct those responsible for the contamination to eliminate the source of pollution and may also supervise whatever clean-up is necessary. If the emergency is major in scope, the DER may require the responsible party to hire a ground-water consultant to work with the DER in the recovery effort. Legal action can be taken of the DER determines the remedial action is not adequate.

Several agencies indicated that an early evaluation at the site of each emergency is an important first step in their emergency response. It is not clear, however, what states other than Pennsylvania have the technical expertise available to offer advice and assistance for emergencies involving ground-water contamination. Only about one-third of the responses stated or implied that such technical expertise is available in state government.

EMERGENCY RESOURCES IN ILLINOIS

To insure that proper corrective action is taken in ground-water pollution emergencies, the input from experts in a number of disciplines is usually necessary. Letters were sent to several Illinois agencies to determine what type of assistance each agency would be able to provide in the event of a pollution incident. The responses are summarized in table 3.

Currently the Illinois Environmental Protection Agency (IEPA) responds to air and water emergencies through an Emergency Response Program, coordinated by the Air Pollution Episode and Emergency Response Section. The section maintains a hotline 24 hours a day to receive phone calls regarding emergencies. Upon notification of a pollution incident, the section informs the technical coordinator from the appropriate Division who is responsible for supervising an investigation and response. Generally the field engineers nearest the scene are asked to visit the site and offer assistance. "A Guide for Control of Emergency Spills of Oil and Other Hazardous Materials" has been prepared by the IEPA for such emergencies. The guide lists the IEPA personnel to which a pollution incident should be reported and summarizes the responsibilities of the IEPA. The emphasis is on surface-water spills. Illinois has no specific strategy for handling ground-water pollution emergencies. However, the IEPA staff includes chemists, engineers, geologists, soil scientists, and lawyers to provide a wide variety of expertise.

Assistance is also available from other state agencies. For example, hydrogeologic information and pertinent advice are available from the Illinois State Geological Survey in Urbana. The Illinois State Water Survey in Champaign offers hydrologic information and expertise. Information about the soil can be obtained from Soil and Water Conservation districts throughout the state or from the Bureau of Soil and Water Conservation in Springfield. Information about the hydrogeology and soils in the area of an emergency is critically important in evaluating each problem and in developing a program of remedial action.

TABLE 3—REPLIES FROM ILLINOIS STATE AGENCIES CONCERNING EXPERTISE AND ASSISTANCE AVAILABLE IN LAND POLLUTION EMERGENCIES

State agency	Assistance available
Bureau of Soil and Water Conservation Illinois Department of Agriculture Emmerson Building Illinois State Fairgrounds Springfield, Illinois 62706 (217) 782-6297	Soil and Water Conservation Districts have soils information that would be useful in the event of a land or ground-water pollution emergency.
Illinois Department of Conservation 605 State Office Building 400 S. Spring Street Springfield, Illinois 62706 (217) 525-6302	This Department's major responsibility concerning water conservation is limited to surface water. Therefore, it would be of little direct assistance.
Illinois Department of Public Health 535 W. Jefferson Street Springfield, Illinois 62702 (217) 782-6550	The Department is able to provide technical advice and/or assistance in the event of an emergency. The staff includes chemists, engineers, health physicists, and laboratory support.
Illinois Emergency Services and Disaster Agency 111 E. Monroe Street Springfield, Illinois 62706 (217) 782-7860	The facilities and equipment of all state agencies are available through this agency. This includes pumps, trucks, medical services, heavy equipment, aircraft, and personnel.
Illinois Environmental Protection Agency 2200 Churchill Road Springfield, Illinois 62706 (217) 782-3637	The IEPA is the coordinating agency for emergencies. The staff includes engineers, geologists, chemists, soil scientists, lawyers, and personnel in regional offices.
State Fire Marshal Division of Fire Prevention 1722 State of Illinois Building 160 N. LaSalle Street Chicago, Illinois 60601 (312) 793-2693	Deputies are available in an emergency involving flammable liquids or chemicals. Deputies determine the source of the problem and require remedial action.
Illinois State Geological Survey Natural Resources Building Urbana, Illinois 61801 (217) 344-1481	The Survey has geologic and hydrogeologic expertise and information available.
Illinois State Water Survey Water Resources Building Champaign, Illinois 61820 (217) 333-2210	The Survey has hydrologic information and expertise available.

When flammable liquids or chemicals are involved in an emergency, the State Fire Marshal's office can be consulted. Deputies from that office are available to evaluate the seriousness of a pollution problem and make recommendations for proper clean-up.

The Illinois Emergency Services and Disaster Agency (ESDA) in Springfield coordinates the use of equipment that may be needed in an emergency. The equipment and facilities of all state agencies are available through the State Emergency Operations Center, which is operated by ESDA 24 hours a day.

To summarize, Illinois has no formal strategy for dealing with groundwater pollution emergencies. However, many resources are available, though scattered throughout several state agencies, for effectively handling such emergencies.

STRATEGIES FOR HANDLING GROUND-WATER POLLUTION EMERGENCIES

From the previous discussion of documented case histories, it is apparent that the development of strategies to deal with all ground-water pollution emergencies is complex. Not only does the hydrogeologic setting change from one site to another, but the potential contaminants vary widely in character. Therefore, strategies must be sufficiently broad to embrace the range of physical conditions and to utilize the pertinent technical expertise available in state government.

The case histories suggest that ground-water pollution incidents fall into two general categories: (1) emergencies requiring an immediate response, and (2) incidents requiring a long-term solution.

Emergency Strategies

Some pollution incidents are immediately serious and require a prompt response to reduce the threat of rapid, extensive environmental damage. Quick action is often of critical importance when water supplies are affected or threatened or when the threat of fire or explosions is present. Such cases are most frequently the result of spills above ground and are recognized immediately. The source is known and the extent of contamination is often limited, especially if remedial action is taken quickly.

The strategy in such cases is to stop further contaminants from entering the subsurface, make an early evaluation of the incident, and take appropriate action to recover the contaminants. Since the nature of the subsurface environment will determine the extent of contamination, a knowledge of earth conditions is necessary for an accurate evaluation and for making recommendations for quick remedial action. If the response is rapid enough, removal of contaminated soil may be sufficient to rectify the situation. However, other techniques may be necessary to recover all the contaminants from the subsurface environment. These will be similar to the longer term renovation techniques discussed following.

Long-Term Strategies

The majority of ground-water pollution incidents in the literature were discovered some time after subsurface contamination began. In many cases, well contamination was the first indication of a ground-water pollution problem. As it may have taken months or years for the contaminants to move from the source to a point of detection, the extent of ground-water contamination is greater than it is for a recent spill. Remedial action is not easy. A long-term renovation program is usually necessary to restore, or even approximate, the original condition of the subsurface environment. Although renovation is the goal, there is generally less urgency for action. Hasty, ill-conceived action may further complicate the situation or cause even wider contamination. Several strategies for such incidents are discussed below.

Elimination of the source of contamination is desirable, but the source may not be readily apparent. Locating the source alone requires some investigation, and it may never be found. Even if the source is identified, it may not be practical to remove the source to stop further contamination; landfill leachate is a good example.

A thorough understanding of the extent of contamination within the earth system is essential for developing an appropriate program of recovery. Therefore, an early effort should be made to define the problem area and the severity of the problem. Available well records for the area may provide information about the hydrogeologic framework. Sampling the water from existing wells may help determine the extent of contamination. Additional borings, backhoe pits, pump tests, or geophysical surveys may be needed to further delineate the earth system and extent of contamination. Once this information has been obtained it can be evaluated, and from it a program for renovation can be developed.

Contaminants can be recovered from the subsurface by several techniques or methods. It is not possible to develop a specific program of remedial action for all situations, but guidelines can be set for preparing recovery programs for future land or ground-water pollution incidents. The expertise and assistance of persons in several disciplines is usually necessary in the preparation and implementation of an effective program of remedial action.

Relation of Hydrogeologic Conditions to Strategies

Inasmuch as the movement of contaminants, and therefore their recovery, is largely dependent on the earth framework, the effectiveness of various recovery techniques will vary with different geologic settings. In general, there are three major geologic environments in Illinois: terrains underlain by fine-grained material, those underlain by coarse-grained material, and those underlain by fractured bedrock.

The hydrogeologic generalizations presented here may serve as a guide for remedial action following a ground-water pollution incident. However, they do not replace the technical expertise in the earth science disciplines that is needed to solve specific pollution problems.

Fine-Grained Materials

Much of Illinois is covered by fine-grained (predominantly clay and silt) deposits of glacial origin that typically have low hydraulic conductivities. Consequently, in these materials movement of ground water and any associated contaminants is slow. In addition, such sediments often afford high attenuation capability. As a result, the zone of contamination is likely to be smaller than it is in coarser materials. This is the type of environment commonly chosen for waste disposal. Although there is some possibility of excessive release of contaminants to an aquifer or to surface water, the principal problem in the areas of fine-grained glacial deposits is the reappearance of contaminants in near-by ditches, roadcuts, and similar places.

Although the affected area may not be large, recovery of the contaminants is likely to be difficult. Pumping wells to recover ground water may be ineffective because of the slow rate of ground-water movement in fine-grained materials. A trench can be installed to intercept the contaminants if the water table is at shallow depth. The determination of the elevation of the water table and direction of ground-water flow is sometimes difficult in materials with very low hydraulic conductivities, but it can be done. Removing the contaminated soil may be the only option in such materials. Monitoring is considered valuable in determining the effectiveness of the recovery program, but in fine-grained materials monitoring presents technical difficulties because of the slow rate of ground-water movement.

Coarse-Grained Materials

Coarse materials (sand and gravel) are present in Illinois as surficial deposits primarily along river valleys, but they also appear locally as glacial outwash. Their hydraulic conductivities are higher, permitting more rapid movement of ground water than is possible in fine-grained sediments. Coarse materials afford some attenuation of contaminants, but it is usually slight.

Pumping wells are an effective tool for recovering subsurface contaminants from coarse-grained materials. Once the affected area has been delineated, one or more wells can be installed to pump ground water and recover the contaminants. Artificial recharge of ground water may be used in conjunction with pumping to flush the contaminants through the earth materials to the recovery wells. This may shorten the length of the renovation program. Monitoring the progress and effectiveness of the program is not particularly difficult.

If the water table is shallow, installation of a trench that intercepts the direction of ground-water movement may be an effective and relatively inexpensive technique for recovery of contaminated ground water. This approach is particularly appropriate for incidents involving petroleum products, which tend to float on the water table.

Fractured Rocks

In parts of Illinois, fractured bedrock is present at or near the land surface. Ground-water movement is along fractures, which are likely to

be irregularly distributed. Contaminants may move rapidly along these openings with little or no attenuation. As a result, contamination frequently follows an irregular distribution pattern, and monitoring wells may not give an accurate picture of the extent of contamination because the various wells may not intercept the same fracture system. Analysis of fracture traces on aerial photographs may indicate the most favorable site for wells (Lattman and Parizek, 1964). However, pumping of affected wells may be more successful than installation and pumping of monitor wells.

When petroleum products are the contaminants, nutrients can be used to break down petroleum products in the subsurface. The use of nutrients in conjunction with pumping may be more effective in recovering the contaminants than pumping alone.

Administrative Strategies

Illinois Environmental Protection Agency

The formulation of a detailed strategy for government agencies dealing with ground-water pollution emergencies is outside the province of the Illinois State Geological Survey. However, inasmuch as the fate of contaminants, whether intentionally or accidently released, is largely controlled by the subsurface environment, earth scientists can provide necessary information for countering ground-water contamination. The following comments regarding administrative strategies, based on information obtained in this study, are made for the purpose of mustering the state's technical resources to deal with pollution incidents.

The Illinois Environmental Protection Agency (IEPA) is the coordinating agency in emergencies involving noise, air, water, and land pollution in the state, and it maintains an Emergency Action Center. A technical coordinator from each division of the Agency provides assistance and advice in the event of emergencies. The Illinois Environmental Protection Agency has an informal program for dealing with ground-water pollution emergencies. If the program were formalized and extended outside the Environmental Protection Agency it could take advantage of expertise available in other agencies of government.

Policy Task Force

A committee or task force is suggested to define the scope of the problem of pollution incidents and develop a formal strategy for dealing with various kinds of ground-water pollution emergencies. This committee could be made up of the director of the Environmental Protection Agency and representatives of each of its divisions, representatives of other state agencies involved in environmental regulation (Department of Public Health, Department of Mines and Minerals, the Department of Conservation, and the Division of Water Resources of the Department of Transportation), and representatives of the various scientific disciplines suggested later in this chapter for the technical advisory board. This committee might consider at an early stage the funding of an emergency response system.

A review of the technical literature and information gathered during this study suggests the need for two levels of response to pollution incidents. The state must be able to react within hours in some instances; in other cases a more deliberate approach is permitted. Therefore, we suggest that two response groups be formed, a pollution response force and a technical advisory board.

Pollution Response Force

The pollution incidents that create serious crises and, therefore, require an immediate response to reduce the threat of rapid, extensive environmental damage could be dealt with by an emergency force consisting of technical specialists, who would make an early evaluation of each ground-water pollution incident and make recommendations for immediate response if necessary. The emergency response force for ground-water pollution emergencies could be formed under the technical coordinator from the Division of Land/ Noise Pollution Control.

The emergency force would be staffed by Environmental Protection Agency personnel to facilitate rapid response to each pollution incident and to keep enforcement authority within the agency to which it has been assigned by state law. Individuals with broad experience and expertise in hydrogeology, hydrology, soil science, inorganic chemistry, and organic chemistry are needed to make an effective group. The group should also be supported by legal counsel. The structure of the emergency force should provide for rapid organization and mobilization in the event of an emergency. A list of necessary equipment and additional technical personnel, which can be drawn from within the Environmental Protection Agency and from other states agencies, should be drawn up for emergency situations. Many of the additional technical personnel may also be members of the technical advisory board. Emergency funds will be necessary for use in those cases in which immediate action by the state is required to prevent serious environmental damage.

Technical Advisory Board

The majority of ground-water pollution cases documented in the literature were not solved quickly or easily. A long-term program was frequently necessary to renovate the subsurface environment effectively. The technical input from many experts may be needed for the preparation of an efficient program of renovation.

The technical advisory board would provide assistance to the Environmental Protection Agency in cases requiring long-term remedial action. Members of the board would also serve as consultants to the emergency response force. The Solid Waste Task Force of the Institute for Environmental Quality has been successful and could be used as a model for the board. To assure continuity, board members should be individuals having the required expertise, not solely representatives of various state agencies or institutions. At least eight scientific disciplines should be represented on the board. The necessary specialists and the state agencies or institutions that employ them are listed on the following page.

1. Land pollution control specialist	— Illinois Environmental Protection Agency—IEPA
2. Hydrogeologist	— Illinois State Geological Survey
3. Hydrologist	— Illinois State Water Survey
4. Health officer	— Illinois Department of Public Health, IEPA, county health departments
5. Soil scientist	— University of Illinois Agricultural Extension, Soil Conservation Service of the U.S. Department of Agriculture
6. Sanitary engineer 7. Organic chemist 8. Inorganic chemist	— IEPA, Illinois Department of Public Health, University of Illinois Institute for Environmental Studies or other departments, other state universities, Metropolitan Sanitary District of Greater Chicago

Additional personnel to be considered for possible inclusion on the board would be an attorney (Illinois Environmental Protection Agency or Attorney General's Office) and a representative of the Emergency Services and Disaster Agency, which coordinates use of equipment for emergencies.

To assist the board in its advisory role, an inventory of all the resources, both public and private, that could be marshalled for remedial action following a ground-water pollution incident should be maintained. The inventory should include, but not be limited to, the location and availability of equipment, the location and capabilities of laboratory facilities, the technical expertise available, and localities where dangerous wastes may be treated or properly disposed. The last item is particularly important.

An important function of the board would be the keeping of records of all cases in which it is involved. Information on the remedial action and its effectiveness can be most valuable in preparing corrective programs for future emergencies. The lack of documentation of complete case histories, from the cause to the effectiveness of responses, has been demonstrated in this report. The board may want to pursue further documentation from unpublished files in other states that were not readily accessible for this study to get a background as complete as possible.

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APPENDIX

Summary and Index of Case Histories

One hundred and sixteen cases of land and ground-water contamination, derived from a review of published literature, from information submitted by agencies of several states and provinces, and from the records of Illinois State Geological Survey personnel, are summarized in this appendix. Each summary gives location, contaminant, source of contamination, effect on the environment, background, geologic setting, remedial action and its effectiveness, and a reference to the source of information. The case histories follow the order of the references that appear at the end of the text.

To facilitate use of the information, the cases have been indexed by source of contamination. A key suggests headings under which eight categories of contaminants can be found in the index. For each source the pertinent case numbers, locations, and contaminants are given.

CASE HISTORY 1

Location: Republic, Missouri.
Contaminant: Sewage.
Source of contamination: Sewage impoundment.
Effect on environment: Several springs and a creek were contaminated with sewage.
Background: In October 1968, a sinkhole collapsed and approximately 4 million gallons of sewage entered ground water through the sinkhole within 24 hours. Most of the sewage reappeared within a mile, but some was detected as much as $1\frac{1}{2}$ miles away.
Geologic setting: The area is underlain by 15 feet of stony clay overlying pinnacled Mississippian limestone.
Remedial action and effectiveness: None reported.
Reference 1.

CASE HISTORY 2

Location: Savannah, Georgia.
Contaminant: Gasoline.
Source of contamination: Unknown.
Effect on the environment: Extensive ground-water contamination.
Background: In 1961, gasoline fumes were detected in a power company manhole and in the power plant building. An investigation revealed no major source, although several small gasoline tanks in the area had leaks.
Geologic setting: The unconfined aquifer consists of fine sand. The static water level is at 6 to 7 feet.
Remedial action and effectiveness: The leaks in the small gasoline tanks were repaired. Initially, 48 well points were installed adjacent to the power plant and pumped to keep gasoline from the manhole. A trench was dug near the power plant and gasoline was burned continuously for 4 months. After a year, the U. S. Geological Survey was consulted. Several wells were drilled to define the extent of ground-water contamination. An estimated 52, 000 square feet of ground water was contaminated with approximately 50, 000 gallons of gasoline. Well points were installed and ground water was pumped, but recovery of gasoline was limited because the film of gasoline on the water table was so thin. Ground water moved slowly, thereby further limiting recovery of gasoline. Later, more pumping was initiated where gasoline accumulation was greatest. By March 1964, about 5000 gallons of gasoline had been recovered, and no new gasoline problems were apparent. A ditch was installed in the direction of natural ground-water flow to collect additional gasoline. Recovery of gasoline remained low. The case was closed in 1966.
Reference 2.

CASE HISTORY 3

Location: Not stated.
Contaminant: Heating oil.
Source of contamination: Pipeline break.
Effect on the environment: Ground water was contaminated throughout an extensive area.
Background: A large refinery noted a serious discrepancy in its records of production for one month. After an extensive search, including pressure testing, oil was found in a new 66-inch storm sewer. Further investigation revealed a leak in a buried section of a 3-inch line as the source of the oil.
Geologic setting: The site is underlain by clean, highly permeable gravel. The water table is at about 5 feet under unconfined conditions.
Remedial action and effectiveness: Action was taken to collect the oil getting into the storm sewer. At the recommendation of a geologist, 90 holes 20 inches in diameter were drilled to delineate the extent of ground-water contamination. A U-shaped collection trench was installed to collect the heating oil, and the collected water and heating oil were pumped to the refinery for separation. Total recovery was about 63,000 barrels of heating oil. It was felt that most of the oil had been recovered.
Reference 2.

CASE HISTORY 4

Location: Not stated.
Contaminant: Fuel oil.
Source of contamination: Pipeline break.
Effect on the environment: Soil and ground water became contaminated.
Background: Within 14 hours, over 8000 barrels of fuel oil escaped an oil transloading point and seeped into the ground before the leak was detected.
Geologic setting: The water table is at a depth of 13 feet under unconfined conditions.
Remedial action and effectiveness: Several pits were dug to below the water table to intercept the ground water and fuel oil. The pits were later replaced by three large-diameter wells, which were pumped continuously. The ground-water contamination was confined within 500 feet of the spill. After one year, no extensive impairment of ground water was found.
Reference 2.

CASE HISTORY 5

Location: Not stated.
Contaminant: Gasoline.
Source of contamination: Leak in storage tank.
Effect on the environment: Explosive concentrations of gasoline fumes were detected in four houses. Ground water was contaminated.
Background: A leak was discovered in a gasoline storage tank at a service station. Further investigation indicated that several thousand gallons of gasoline had been lost over a period of at least 3 weeks.
Geologic setting: All the affected houses and some not affected had been built over an old creek bed that had been filled with rip-rap and coarse rock. The fill had settled, causing undermining and cracking of basement floors. Gasoline followed the creek bed, and fumes entered the affected homes through the cracks in the basement floors.
Remedial action and effectiveness: Initially, the local Fire Department poured water through the cracks in basements to dissipate the fumes, but with little success. Water and a dispersant were then used, again without much success. In two of the houses, basement floors were replaced with new slabs that had a vapor seal, and the houses were reoccupied. The other two houses remained unoccupied for several months, and the fumes gradually dissipated. No mention was made of any effort to restore ground water.
Reference 2.

CASE HISTORY 6

Location: Los Angeles and Glendale, California.
Contaminant: Gasoline.
Source of contamination: Unknown.
Effect on the environment: Ground water was contaminated throughout a large area. It became necessary to shut down one well field.
Background: In 1968, a large volume of gasoline was discovered on the relatively flat water table between two major cones of pumping for municipal water supplies. One cone of pumping contained Glendale's Grandview well field and the Los Angeles Crystal Spring wells; the other cone contained the Los Angeles Pollock wells. Preliminary estimates set the volume of gasoline on the water table at about 250,000 gallons. A buried gasoline pipeline in the area was found to be leaking and its use was discontinued. It was never positively identified as the source of the problem.
Geologic setting: The affected shallow aquifer consists of sand and gravel with interbedded silt and clay. The aquifer is semiconfined in places and is 150 to 250 feet thick.
Remedial action and effectiveness: The Pollock well field was shut down in November 1969 to prevent contamination of those wells. No source was positively identified, so the Western Oil and Gas Association (WOGA) began a drilling and pumping program to define the extent of ground-water contamination and contain the zone of contamination to reduce the spread of gasoline. As of August 1971, about 70 wells had been drilled. About 50,000 gallons of gasoline were recovered by 1971. It is believed most of the free gasoline has been removed and that natural breakdown of gasoline by bacteria will eliminate the gasoline still present in the ground. Monitoring continues.
References 2 and 71.

CASE HISTORY 7

Location: Brookings, South Dakota.
Contaminant: Leachate.
Source of contamination: Landfill.
Effect on the environment: Ground water was contaminated as much as 1000 feet away from the landfill site in the direction of ground-water movement. There was little lateral dispersion.
Background: A study was made to determine whether the landfill was contaminating ground water. Twenty-two wells were drilled to determine the extent of contamination.
Geologic setting: The site is an abandoned sand and gravel quarry. The surficial outwash deposits are 12 to 31 feet thick and consist of discontinuous lenses of sand and gravel intermixed with some clay and silt. The static water level is at a depth of 6.5 feet. Ground-water movement in the unconfined aquifer is to the southwest.
Remedial action and effectiveness: A trench was installed along the southern boundary of the landfill to intercept contaminated ground water and provide at least partial treatment by dilution and dispersion. Ground-water quality improved.
References 3 and 4.

CASE HISTORY 8

Location: New Castle County, Delaware.
Contaminant: Leachate.
Source of contamination: Landfill.
Effect on the environment: A large zone of ground water was contaminated. Leachate was moving toward (1)

water-supply wells about 5000 feet from the landfill that pump 4 to 5 million gallons per day, and (2) wells supplying water for a chemical plant.

Background: A complaint of well pollution in 1972 led to an investigation. The ground-water contamination was traced to the Llangollen landfill some 800 feet away. The landfill, which operated between 1960 and 1968, was originally a dump and received various unknown types of industrial wastes. When the landfill was operating, some of the clay beneath the site was removed for cover material, permitting movement of leachate to the underlying aquifer.

Geologic setting: Refuse was placed in an abandoned sand quarry in the Columbia Formation of Pleistocene age. A thin clay layer is sandy in places and is absent beneath part of the site. Beneath the clay is the major aquifer for the area, the unconsolidated sand, silt, and clay of the Potomac Formation. This aquifer is confined beneath the clay. Ground-water movement is generally toward the Delaware River, but it is influenced by the high-yield wells in the region.

Remedial action and effectiveness: About 100 wells or borings have been made to date to determine the extent of ground-water contamination. Wells have been installed near the landfill to reverse the flow of ground water back toward the landfill, and they are pumping about 3 million gallons per day. Pumpage in both the water-supply wells and the wells of the plant has been cut back, and water is obtained from other sources. An increase in the number of wells to intercept more leachate has been considered. An estimated 10 years would be necessary to renovate the aquifer adequately. Removal of the landfill may be necessary. About 30 private wells in the contaminated area have been replaced with a public water supply.

References 5 and 22; personal communication from Michael Apgar of the Delaware Department of Natural Resources and Environmental Control.

CASE HISTORY 9

Location: Tieton, Washington.

Contaminant: Sewage.

Source of contamination: Sewage impoundment.

Effect on the environment: Several private wells as much as 2000 feet down the valley from the lagoon became contaminated.

Background: The contamination was traced to a sewage lagoon constructed to dispose of sewage wastes from Tieton by evaporation and infiltration. Percolation rates were as high as 15 inches per day.

Geologic setting: Tieton lies in a valley formed by a series of parallel basalt anticlines. A series of permeable sands and gravels of fluviatile and glaciofluviatile origin overlie the basalt. The surficial material ranges from 20 to 200 feet thick. Ground-water flow appears to be down-valley. The porous surficial material permits rapid ground-water movement. Velocities in excess of 300 feet per day were measured.

Remedial action and effectiveness: Damages were awarded to those whose wells had been contaminated. Nothing apparently was done to eliminate the leaky sewage lagoon or restore ground water.

Reference 8.

CASE HISTORY 10

Location: Michigan.

Contaminant: Industrial wastes.

Source of contamination: Impoundments.

Effect on the environment: Shallow ground-water aquifer was contaminated.

Background: Pollution of an industrial supply well was noted during plant expansion. The pollution was traced to the plant's waste ponds. Investigation revealed that 90 percent of the wastes was cooling water, $2\frac{1}{2}$ percent was sewage, 5 percent could be treated and discharged to surface waters, and $2\frac{1}{2}$ percent was highly concentrated complex waste.

Geologic setting: Sandy lake deposits form an unconfined aquifer 60 to 120 feet thick. The water table is at a depth of about 5 feet. An aquiclude consisting of a clay layer is present between the sand aquifer and an underlying bedrock aquifer, which was apparently unaffected.

Remedial action and effectiveness: An investigation was made of the extent of ground-water contamination, the nature of the wastes, and the aquifer characteristics. A new industrial water supply was developed. Ponds were built and cooling water was recharged to ground water. No consideration of possible thermal contamination of ground water was mentioned. Waste treatment ponds were constructed for other wastes. Purge wells were installed. No information was given on pumping rates or length of pumping. The purge wells had to be redeveloped periodically because of the nature of the wastes. Pumping apparently continued from 1967 to at least 1971. The zone of contamination has been confined and water quality has continued to improve.

Reference 9.

CASE HISTORY 11

Location: West Chicago, Illinois.

Contaminant: Industrial waste.

Source of contamination: Waste impoundment.

Effect on the environment: A zone of ground-water contamination extended more than 4000 feet in the direction of ground-water movement.

Background: A 1962 report prepared by the Illinois Geological Survey and the Illinois Water Survey indicated an area of mineralized ground water in West Chicago. Butler designed a study to determine the source and extent of ground-water mineralization. The contamination was traced to a seepage lagoon used by a chemical plant to dispose of its wastes—1.6 million gallons of waste water were discharged to this lagoon weekly. The bottom of the lagoon is in sand. The contaminants apparently moved through the glacial drift to the dolomite aquifer.

Geologic setting: The area is underlain by approximately 80 feet of unconsolidated glacial deposits consisting of till, silt, and discontinuous sand and gravel lenses. The drift is underlain by Silurian dolomite, which serves as the major source of water in the area. In much of the region, the drift aquifer and dolomite aquifer are in hydraulic connection. The water table is generally only a few feet below the surface.

Remedial action and effectiveness: None reported.

Reference 10.

CASE HISTORY 12

Location: Riverside, California.
Contaminant: Leachate.
Source of contamination: Landfill.
Effect on the environment: Ground-water contamination extended as much as a mile from the landfill in the direction of ground-water movement. Apparently the entire thickness of the shallow aquifer was affected.
Background: In the early 1950s a study of possible ground-water contamination from a "typical" landfill was begun. The landfill operated for several years as an open dump before it was converted to a sanitary landfill in 1948. Apparently the initial filling had been placed in standing water.
Geologic setting: The site is underlain by an upper aquifer consisting of fine- to coarse-grained sand, a thin, discontinuous silt and clay layer, and a lower aquifer of medium- to coarse-grained sand. The static water level for the upper aquifer is near the base of the refuse. The silt and clay layer acts to retard movement between the two aquifers. There is no indication that the lower aquifer was affected by the landfill operation.
Remedial action and effectiveness: None reported.
References 11 and 14.

CASE HISTORY 13

Location: Montebello, California.
Contaminant: Industrial wastes.
Source of contamination: Improper waste disposal of chlorinated phenols.
Effect on the environment: About 12 water wells became contaminated.
Background: Contamination of several shallow wells in 1945 was traced to the disposal of wastes from a plant manufacturing weed killer in Alhambra, California. The wastes were discharged to a sewer system, traveled through the sewage treatment plant, and were discharged to the Rio Hondo River, where they mixed with ground water and affected the wells near the river. The wells became contaminated only 2 weeks after the wastes reached the sewage treatment plant.
Geologic setting: No information given.
Remedial action and effectiveness: The manufacturing plant was shut down. Treatment of the wells with chlorine dioxide was necessary to eliminate the contaminant.
Reference 12.

CASE HISTORY 14

Location: Indianapolis, Indiana.
Contaminant: Leachate.
Source of contamination: Landfill.
Effect on the environment: Two water-supply wells were contaminated.
Background: In 1931 two water-supply wells became contaminated. The contamination was traced to an earthen pit, which had been built 8 to 9 months earlier for disposal of liquor from "cooked garbage." The nearest affected well was 500 feet away.
Geologic setting: The two contaminated wells were finished in a shallow gravel aquifer to a depth of 80 feet. The gravel is 100 feet thick and overlies limestone bedrock.
Remedial action and effectiveness: The wells were abandoned. A new water supply was used.
Reference 13.

CASE HISTORY 15

Location: Dunreith, Indiana.
Contaminant: Acetone cyanohydrin.
Source of contamination: Hazardous chemical spill.
Effect on the environment: The spill resulted in soil, surface-water, and ground-water contamination. Several thousand fish and a few farm animals were killed by the cyanide.
Background: A railroad tank car accident resulted in an explosion, a fire, and the spilling of hazardous chemicals. Some 1200 gallons of acetone cyanohydrin percolated into the railroad bed and down a tile drain into Buck Creek, which supplied water to a downstream municipality. Concentrations of cyanide in Buck Creek were as high as 405 mg/l. The maximum safe level is 20 mg/l.
Geologic setting: No information given.
Remedial action and effectiveness: Over 3 tons of calcium hypochlorite was dumped into Buck Creek to deactivate the cyanide before it reached downstream water users. This approach was apparently successful. Near-by well owners were notified to cease use of their wells. A sampling program to test for contamination of ground water continued into April. Contaminated water was pumped from the ground, treated, lagooned, then fed to surface water. April snowmelt flushed additional cyanide into ground water. Roadbed materials were decontaminated. The remedial action was apparently successful. However, the polluted waters were not noticed quickly enough, and serious consequences could have resulted. A better understanding of local water-use patterns and immediate recognition of possible water contamination might have averted some of the animal deaths and the hazard to human life.
References 15 and 44.

CASE HISTORY 16

Location: Indianapolis, Indiana.
Contaminant: Chlorides.
Source of contamination: Salt storage area.
Effect on the environment: Several shallow wells were contaminated.
Background: Several well owners complained of deterioration of water quality, beginning in 1967. The contamination was traced to a near-by salt storage area, which had been placed in service in 1966. Runoff from the salt pile to a ditch near by served to increase the extent of contamination.
Geologic setting: The affected wells were finished in a shallow glacial drift aquifer at a depth of 30 to 36 feet. The drift is about 100 feet thick and consists of alternating beds of clay, silt, sand, and gravel, or mixtures of those materials. Ground-water movement was in the direction of the affected wells.

Remedial action and effectiveness: The salt pile was removed in 1968. The salt company paid for the installation of city water lines. Some residents took this water, abandoning their wells. By 1973, chloride concentrations in the most severely affected residential wells had dropped to 350 mg/l by natural flushing and dilution.
Reference 16.

CASE HISTORY 17

Location: Bronson, Michigan.
Contaminant: Plating wastes.
Source of contamination: Impoundments.
Effect on the environment: Shallow ground-water contamination affected a private well. Contamination was apparently confined to the upper portion of the shallow aquifer.
Background: In 1949, a shallow domestic well was found to be contaminated with chromium. The contamination was traced to leakage from two ponds of a major plating company. Apparently a ground-water mound had formed beneath the ponds.
Geologic setting: Information for the area suggests the upper and lower drift aquifers are separated by a clay layer. The water table is at a depth of about 8 feet.
Remedial action and effectiveness: None reported.
Reference 17.

CASE HISTORY 18

Location: New Annan, Prince Edward Island, Canada.
Contaminant: Organic wastes.
Source of contamination: Impoundments.
Effect on the environment: At least six private wells were contaminated.
Background: In January 1972, several residents reported contaminated wells. The problem was traced to waste operations at a near-by farm. Land disposal of organic wastes (e.g., pea vines and potato screens) and improper lagooning of wastes were thought to have contributed to the ground-water contamination.
Geologic setting: All the contaminated wells were completed in the same shallow aquifer. The water table is near the surface. Ground-water movement is along fractures in bedrock.
Remedial action and effectiveness: None mentioned.
Reference 18.

CASE HISTORY 19

Location: Southeastern Pennsylvania.
Contaminant: Fuel oil.
Source of contamination: Storage tank leak.
Effect on the environment: Both surface water and ground water were contaminated. An estimated 60,000 gallons of fuel oil were lost.
Background: Fuel oil appeared on a stream in 1967. An investigation traced the fuel oil to a leak in a buried 10,000-gallon tank.
Geologic setting: Miscellaneous fill is present over shallow schist bedrock. Ground-water movement is toward the stream. The static water level is at a depth of 5 to 8 feet.
Remedial action and effectiveness: Wells were drilled to define the hydrogeology and the path of ground-water movement. Up to 5 feet of oil was found on the water table. About 13,000 gallons of oil were pumped out by the defendant, but the flow of oil to the stream was not stopped. Legal action was necessary, which prevented prompt action to correct the problem. Enzymes were used by the defendant in the summer of 1971 with inconclusive results. A new program was initiated in mid-1972. A trench was dug between the tank and the stream and a pipe installed to help collect oil. A large-diameter well was installed and was pumped continuously, beginning in mid-1973. Water and fuel oil were separated and the water discharged to a stream. Most of the oil was recovered by bailing the existing wells. Recovery of oil was about 5 gallons per week, except during a 1-month period when the water table was low; oil recovery increased to 100 gallons per week. About 600 gallons were recovered before a drop in recovery caused the pumping operation to be terminated. A thin film of oil remains on the shallow water table. The long delay caused by legal problems prevented prompt action that might have proved more effective in cleaning up the pollution with less effort. It is difficult to determine how much oil was recovered.
Reference 19 and information from the files of the Pennsylvania Department of Environmental Resources.

CASE HISTORY 20

Location: Central Pennsylvania.
Contaminant: Leachate.
Source of contamination: Landfill.
Effect on the environment: A spring, ground water, and surface water were contaminated.
Background: In 1969, a spring was buried by refuse from a dump. As a result, leachate was produced that discharged to a near-by stream at 4 to 5 gallons per minute.
Geologic setting: The site is underlain by the Martinsburg Shale, a thin-bedded, jointed bedrock. Weathered shale is present at the surface to a depth of 8 to 12 feet. The water table is at a depth of about 35 to 40 feet.
Remedial action and effectiveness: Remedial action was begun in 1969. The operation was converted to a sanitary landfill. The irregular topography of the site was smoothed and a final cover of soil was applied. A drainage channel was formed to divert surface water. A pit with porous concrete walls was constructed at the site of the buried spring to collect the leachate. The leachate was then transferred to a clay-lined impoundment for evaporation. Consideration is being given to recycling the leachate through the fill.
Reference 20.

CASE HISTORY 21

Location: Miller County, Arkansas.
Contamination: Chlorides.

Source of contamination: Improper waste disposal.
Effect on the environment: About 1 square mile of the shallow aquifer was affected.
Background: In 1967, a farmer complained of salty water in his irrigation well. The contamination was traced to an oil-field brine disposal pit some 2500 feet away. Once the use of the pit was stopped, the waste brine was discharged through an abandoned oil well. Corroded casing had permitted further ground-water contamination before the source was found.
Geologic setting: The site is on the floodplain of the Red River. The zone of ground-water contamination is largely within the shallow aquifer, which consists of about 12 feet of clay overlying alluvial sand and gravel to a depth of about 40 feet. The water table is at a depth of about 10 feet.
Remedial action and effectiveness: A proper disposal well was dug to take future brines. Consideration was given to several renovation methods, including containment with a bentonite wall, accelerated discharge of ground water, use of the contaminated ground water, and deep well disposal. All were rejected because of cost. An estimated 250 years will be necessary for natural flushing to restore the affected aquifer.
Reference 21.

CASE HISTORY 22

Location: Rockaway Beach, Long Island, New York.
Contaminant: Gasoline.
Source of contamination: Unknown.
Effect on the environment: Shallow ground water was contaminated.
Background: Raw gasoline was detected in shallow deposits in the business district of Rockaway Beach. The source was never positively identified.
Geologic setting: No information given.
Remedial action and effectiveness: A massive excavation project was undertaken so that the contaminated water could be removed to prevent a fire or explosion. Shallow observation wells were installed to define the water table and area of contamination. An entire city block was dug out and pumps were used to remove the gasoline.
Reference 23.

CASE HISTORY 23

Location: Southeastern Pennsylvania.
Contaminant: Gasoline.
Source of contamination: Pipeline break.
Effect on the environment: Two public water-supply wells became polluted with gasoline.
Background: An investigation as a result of well pollution in the summer of 1971 revealed that a 14-inch pipeline carrying a gasoline product had ruptured, and approximately 134,000 gallons of the product had been lost. One well was 300 feet and the other 400 feet from the pipeline break.
Geologic setting: The site is underlain by an unconfined aquifer that consists of highly fractured, cavernous limestone.
Remedial action and effectiveness: Immediate action by the pipeline company resulted in recovery of about 47,000 gallons of gasoline. Approximately 90,000 gallons reached ground water. The municipal wells were pumped to waste to depress the water table and minimize the spread of contaminants. Five wells were installed initially to recover the gasoline and to determine the extent of contamination. Ultimately, 48 wells were drilled. Ground water and gasoline were pumped through an oil separator, and about 30,000 gallons were recovered this way in about 9 months. Recovery finally dropped to nearly nothing. A plan was then implemented to feed the gasoline-degrading bacteria in ground water by adding nutrients in the form of phosphates and nitrates. Oxygen was added to maintain aerobic conditions in the aquifer. This program, combined with continuous pumping, has proved effective, an estimated 30,000 gallons of gasoline being recovered by early 1974. The program has now been terminated. The pipeline company has been supplying water to the municipality since the spill. The original municipal wells have not been put back in service.
Reference 24 and information from the files of the Pennsylvania Department of Environmental Resources.

CASE HISTORY 24

Location: Spring Mills, Pennsylvania.
Contaminant: Gasoline.
Source of contamination: Storage tank leak.
Effect on the environment: Ground water was contaminated. An explosion from gasoline fumes resulted in about $8000 in property damage.
Background: A well exploded in June 1970. The well had been hand dug to 80 feet and later drilled to 272 feet. Investigation revealed that a near-by underground storage tank had lost 200 to 250 gallons of gasoline in the 2 weeks prior to the explosion. This gasoline was suspected as the source of the explosion.
Geologic setting: The site is underlain by well jointed, fine-grained limestone. Unconfined ground-water movement is along fractures. The water table is at a depth of about 92 feet.
Remedial action and effectiveness: None reported.
Reference 25.

CASE HISTORY 25

Location: Ledyard, Connecticut.
Contaminant: Industrial waste containing styrene.
Source of contamination: Land disposal of wastes.
Effect on the environment: Ground water was contaminated.
Background: Six private wells became contaminated with styrene—an aromatic hydrocarbon—in 1962. An investigation revealed that styrene had been used to burn brush in clearing land for the housing development at which the wells became contaminated. Barrels partially filled with styrene had been buried at two different locations. The affected wells were within about 300 feet of the barrels.

Geologic setting: The surficial deposit is a sandy, silty, and gravelly till with some clay and boulders. Depth to bedrock varies from 7 to 16 feet, with an average of 10 feet. The affected wells obtain water either from schist of Cambrian age or granite gneiss of Mississippian or older age. Bedrock is fractured. The static water level in the wells varies from 16 to 22 feet. Movement of the styrene was along fractures in the unconfined aquifer.

Remedial action and effectiveness: All known contaminating material was removed from the ground. Activated charcoal filters were installed in the wells in 1962. Concentrations of styrene fluctuated seasonally and in response to precipitation. By 1964, no styrene was detected in any of the wells.

Reference 28.

CASE HISTORY 26

Location: Kentucky, adjacent to the Ohio River.

Contaminant: Hydrochloric acid.

Source of contamination: Broken discharge line.

Effect on the environment: Four industry production wells became contaminated.

Background: A break in an industry's waste discharge line occurred in March 1967 as a result of a 49-foot rise of the Ohio River. An unknown volume of hydrochloric acid entered ground water that is used by the industry in its processing and for cooling water. The affected wells had produced 1.9 million gallons of water per day.

Geologic setting: The site is underlain by about 100 feet of Pleistocene sand and gravel, adjacent to the Ohio River. The river is influent. The sand and gravel aquifer is unconfined.

Remedial action and effectiveness: Four wells were installed initially to locate the cause of the problem. One contaminated well was pumped to remove the contaminant. However, movement was slow when river level was low. Chloride concentrations were found to increase with high river levels, as did the movement of ground water. Pumping was stopped after a year because of deterioration of the well. Another well was drilled about 2000 feet from the spill and, with a well 1500 feet away, is used as the industrial supply. Two other affected wells are used as a secondary source. Surveillance of ground-water contamination continues.

Reference 29.

CASE HISTORY 27

Location: Wisconsin.

Contaminant: Industrial waste—spent sulfite liquor.

Source of contamination: Seepage pit.

Effect on the environment: Shallow ground water was contaminated.

Background: A study was initiated in 1969 to determine the feasibility of the use of resistivity measurements to monitor movement of a contaminant. Wastes were discharged to a seepage pit at a rate of 9000 gallons per day for 5 days.

Geologic setting: The static water level was encountered at a depth of 1 to 3 feet; the water table is fairly flat and is unconfined. Fine-grained sand is present to a depth of 10 feet, peat from 10 to 19 feet, and fine to coarse sand from 19 to 27 feet. The peat retards downward ground-water movement.

Remedial action and effectiveness: Resistivity measurements were successfully used to trace the movement of the contaminant in ground water. No other action was reported taken.

Reference 30.

CASE HISTORY 28

Location: Elgin, Illinois.

Contaminant: Leachate.

Source of contamination: Elgin landfill.

Effect on the environment: Ground-water contamination is limited to the landfill site and the area between the fill and the Fox River.

Background: Filling began in 1968. Wastes have included both household garbage and industrial wastes. A study was made of the hydrogeologic and water-quality conditions at the site.

Geologic setting: The site is underlain by up to 9 feet of sand and gravel, much of which was removed during quarrying activity prior to landfill operations. Sandy silt till is present beneath the sand and gravel; although the till varies in thickness from 5 to 39 feet, it is generally about 15 feet thick. Sand and gravel are present above dolomite bedrock of Silurian age. The water table is at a depth of 10 to 20 feet, with ground-water movement toward the Fox River, which flows just east of the landfill.

Remedial action and effectiveness: None reported.

Reference 31.

CASE HISTORY 29

Location: Woodstock, Illinois.

Contaminant: Leachate.

Source of contamination: Woodstock landfill.

Effect on the environment: Ground-water contamination is limited to the fill area.

Background: The landfill has been operated since 1940. It was an open burning dump until 1965, when it was changed to a sanitary landfill. A study was made of the hydrogeologic and water-quality conditions at the site.

Geologic setting: In the southern two-thirds of the site, refuse was placed in a swamp. The material consists of 5 to 19 feet of peat and inorganic silt. Five to 19 feet of sand and gravel is present beneath the entire site. Till with some interbedded sand and gravel is present to a depth of more than 225 feet. Bedrock is shale and dolomite of the Maquoketa Shale Group. A ground-water mound exists within the refuse in the southern part of the landfill. The static water level is at a depth of 5 to 10 feet.

Remedial action and effectiveness: None reported.

Reference 31.

CASE HISTORY 30

Location: Winnetka, Illinois.

Contaminant: Leachate.

Source of contamination: Winnetka landfill.
Effect on the environment: Ground-water contamination is limited to the fill area.
Background: The site has been used for disposal since 1947. A study was made of the hydrogeologic and water-quality conditions at the landfill.
Geologic setting: The landfill is underlain by 5 to 11 feet of alluvium (sandy clay and silt); 5 or 6 feet of a transition zone (fine sand, silt, and clay); and 96 to 100 feet of silty clay till. Silurian dolomite bedrock is encountered at depths of more than 100 feet. A ground-water mound has formed within the landfill; ground-water flow is therefore away from the landfill on all sides.
Remedial action and effectiveness: None reported.
Reference 31.

CASE HISTORY 31

Location: Du Page County, Illinois.
Contaminant: Leachate.
Source of contamination: Old Du Page County landfill.
Effect on the environment: Some deterioration in water quality is apparent away from the landfill, but ground-water contamination is generally limited to the fill area.
Background: The landfill was operated from 1952 to 1966. A study was made of the hydrogeologic and water-quality conditions at the landfill.
Geologic setting: The site is underlain by 10 to 21 feet of sand above 5 to 25 feet of silty clay till. Silurian dolomite bedrock is encountered at about 60 feet. A ground-water mound, which is reflected by a number of seeps and springs around the perimeter of the landfill has developed at the site. The water table is at a depth of about 5 to 10 feet. Most ground-water movement is through the more permeable surficial sand.
Remedial action and effectiveness: None reported.
Reference 31.

CASE HISTORY 32

Location: Barstow, California.
Contaminant: Industrial wastes, sewage, detergents.
Source of contamination: Improper waste disposal.
Effect on the environment: Ground-water contamination extends downgradient 4 miles from the source. A well field is threatened.
Background: Complaints of well contamination began in 1952. Several wells were abandoned. Previous investigations traced the contamination to local municipal and industrial waste disposal. A study initiated by the U. S. Geological Survey to evaluate the ground-water degradation in this area found ground water degraded by (1) natural ground-water inflow, (2) industrial and municipal waste disposal from several sources, and (3) irrigation-return water. Data suggest two plumes of contamination, an old plume near the base of the aquifer and a shallow plume produced by more recent contamination.
Geologic setting: The area is underlain by unconsolidated alluvial deposits of Pleistocene and Holocene ages. Sand and gravel predominate. The shallow aquifer is recharged by the Mojave River. Wells in this aquifer yield from several hundred to over 1000 gallons per minute.
Remedial action and effectiveness: None reported.
Reference 32.

CASE HISTORY 33

Location: South Elgin, Illinois.
Contaminant: Leachate.
Source of contamination: Landfill.
Effect on the environment: The shallow ground-water aquifer was contaminated.
Background: A landfill was operated on a 45-acre site for several years. Monitoring wells installed in the shallow sand and gravel aquifer detected ground-water contamination about 1970. The monitoring wells had been placed between the landfill and the South Elgin well field.
Geologic setting: The shallow monitoring wells are finished in a shallow, unconfined, sand and gravel aquifer that is underlain by a buffer zone of clay at least 9 feet thick. The clay retards movement between the sand and gravel aquifer and the underlying dolomite aquifer. No pollution has been indicated in the lower aquifer, in which the South Elgin wells are completed.
Remedial action and effectiveness: In 1972, the operators of the landfill were fined $10, 000 by the Illinois Pollution Control Board for causing ground-water contamination and posing a potential threat to the South Elgin well field. In 1975, a permit was issued for use of the site for inert materials to bring the site up to grade for closing. The permit provides for some collection and treatment of surface leachate. Monitoring continues to show ground-water contamination of the shallow aquifer.
Reference: Illinois Environmental Protection Agency files.

CASE HISTORY 34

Location: Charleston, Illinois.
Contaminant: Cyanide.
Source of contamination: Spill.
Effect on the environment: Soil and ground water were contaminated.
Background: In October 1969, a Penn Central train derailed and spilled about 15, 000 gallons of cyanide on the ground. Most of the cyanide apparently percolated into the ground.
Geologic setting: About 3 feet of soil is present over 12 feet of yellow clay. The static water level is at a depth of 4 feet.
Remedial action and effectiveness: Response to the spill was fairly rapid. A trench was dug around the perimeter of the contaminated area to the top of the clay. Standing surface water was treated with calcium hypochlorate. Well points were installed within the contaminated area. A septic system was installed to collect contaminated ground water. Ground water was pumped to tanks and treated with chloride before discharge to a railroad ditch. In early 1970, an agreement was made between the railroad

and the Illinois Environmental Protection Agency for further testing and treatment. A lined lagoon, in which the contaminated soil could be treated, was installed. Ground-water recharge to accelerate flushing and pumping to keep the contamination from spreading continued until March 1971. The effectiveness of this program was limited by the fine-grained nature of surficial material. Tests indicated that the cyanide had penetrated to a depth of only 3 to 4 feet. Therefore, the most contaminated soil was removed to the lined lagoon and treated with HTH. Treatment was terminated in November 1973. The Illinois Environmental Protection Agency continued to monitor the site until 1975. The remedial action has apparently been effective.

Reference: Illinois Environmental Protection Agency files.

CASE HISTORY 35

Location: Near Byron, Illinois.

Contaminant: Hazardous industrial wastes, including cyanide, arsenic, cadmium, chromium, and phenols.

Source of contamination: Land disposal of wastes.

Effect on the environment: Soil, surface water, and ground water were contaminated with toxic materials.

Background: An investigation was begun in 1974 following the discovery of three dead cattle in a stream. It was determined that the cattle had died of cyanide poisoning. The investigation disclosed that a 5-acre site had been used for several years for the disposal of toxic wastes. The site contained at least 1511 containers of industrial wastes, including cyanide and heavy metals. Contamination was most noticeable following precipitation.

Geologic setting: The glacial drift on the site is generally less than 5 feet thick. It consists of loess above sandy loam till and residual soil over bedrock. The units are thin and discontinuous. Bedrock is dolomite of the Galena and Platteville Groups. Most domestic wells are finished in the Galena-Platteville.

Remedial action and effectiveness: The waste drums were removed from part of the affected area. About 1000 of the drums contained spent cyanide, which was incinerated. Earthen dams were constructed to control runoff. Calcium hypochloride was used to treat cyanide in runoff. An investigation by the Illinois Environmental Protection Agency and the Illinois State Geological Survey was begun to determine the extent of ground-water contamination and possible remedial measures.

References 60 and the files of the Illinois Environmental Protection Agency.

CASE HISTORY 36

Location: Mapleton, Illinois.

Contaminant: Acrylonitrile (vinyl cyanide).

Source of contamination: Spill.

Effect on the environment: Soil and ground water were contaminated. Several wells were affected.

Background: A train belonging to the Toledo, Peoria, and Western Railroad derailed December 23, 1973, spilling about 20,000 gallons of acrylonitrile on the ground, where some of the liquid formed pools.

Geologic setting: No information given.

Remedial action and effectiveness: The Illinois Environmental Protection Agency ordered use of near-by wells to be discontinued. The railroad was at first reluctant to assume responsibility for the spill. After several months, borings were made to determine the extent of contamination. Sixteen wells were installed and monitored; five proved to contain acrylonitrile. Contaminated ground water was pumped out and taken to a sewage treatment plant for treatment. In April 1974, 5 to 8 feet of contaminated soil was removed and taken to a landfill for disposal. Ground-water quality improved to such a point that the case was closed.

Reference: Illinois Environmental Protection Agency files.

CASE HISTORY 37

Location: Springfield, Illinois.

Contaminant: Leachate.

Source of contamination: Landfill.

Effect on the environment: Ground water in at least two monitoring wells was contaminated.

Background: Sampling of monitoring wells in late 1972 revealed ground water was being contaminated by a landfill operation.

Geologic setting: The site is underlain by sand on the floodplain of the Sangamon River. Ground-water movement in the shallow, unconfined sand aquifer is toward the Sangamon River, some 700 feet away.

Remedial action and effectiveness: A permit was issued by the IEPA for a new landfill site, which will result in the closing of the old site. Ground-water contamination continues.

Reference: Illinois Environmental Protection Agency files.

CASE HISTORY 38

Location: Rockford, Illinois.

Contaminant: Leachate.

Source of contamination: Landfill.

Effect on the environment: A public supply well, several industrial wells, and a number of private wells were contaminated.

Background: In late 1971, contamination of a public water supply well became apparent when methane was detected in wells and in near-by homes. An investigation traced the source of contamination to a near-by landfill. Several industrial wells had previously shown contamination and their use had been discontinued.

Geologic setting: The landfill was located in an abandoned sand and gravel quarry. Apparently the affected wells were finished in the shallow, unconfined sand and gravel aquifer.

Remedial action and effectiveness: At the request of the superintendent of the Rockford Water Department, a ground-water recovery program was developed by the Illinois State Geological Survey and State Water Survey. The plan recommended pumping

ground water and recovering methane. The proposal was never implemented. Legal action was taken in early 1974 by the Illinois Environmental Protection Agency. An agreement was reached whereby the site was closed and covered. Several homes whose wells had been affected were provided with public water. Remedial action following contamination of the initial well might have limited the spread of contamination.

References: Illinois State Geological Survey files and Illinois Environmental Protection Agency files.

CASE HISTORY 39

Location: Aurora, Illinois.

Contaminant: Leachate.

Source of contamination: Landfill.

Effect on the environment: Ten private wells were contaminated.

Background: In February 1966, the Illinois Department of Public Health received a complaint of well contamination. An investigation was conducted by the Health Department and the Illinois State Geological Survey, which included sampling wells, measuring water levels, drilling test wells, and making dye tests. The investigation indicated a near-by landfill was the source of contamination. Apparently ground-water contamination was related to the disposal of solid waste in standing water on the landfill site. The Geological Survey had investigated the site as a proposed landfill site in 1959 and had determined that there was a potential for groundwater contamination.

Geologic setting: The landfill is on the floodplain of the Fox River in an abandoned sand and gravel quarry. The surficial materials are underlain by fractured dolomite, which serves as the source of ground water for the affected wells. Ground-water movement was determined to be toward the Fox River. The contaminated wells, completed in shallow dolomite, were located between the landfill and the river.

Remedial action and effectiveness: On December 1, 1966, a Kane County Circuit Court Judge awarded $88,000 to seven residents whose wells had been affected. An effort was made to have public water provided to those whose wells had been contaminated. The landfill was closed in September 1974.

References: Illinois State Geological Survey files and Illinois Environmental Protection Agency files.

CASE HISTORY 40

Location: Lake County, Illinois.

Contaminant: Acid wastes.

Source of contamination: Impoundment.

Effect on the environment: Both surface water and ground water were contaminated. Apparently only one well was affected.

Background: A complaint of contamination of a private well was made to the Illinois Environmental Protection Agency in December 1973. An investigation traced the source to an industrial waste leaching pit some 50 feet from the affected well. In addition, acid wastes were stored in open barrels near by. There was evidence of spillage and discharge to near-by Lily Lake.

Geologic setting: The wells in the area are shallow sandpoint wells that obtain water from a sand interval at depths of 25 to 30 feet.

Remedial action and effectiveness: The responsible industry agreed to have the industrial wastes hauled away. Shortly thereafter, the industry moved to a new location and legal action by an environmental group was dropped. The owners of the contaminated well drilled a new well to a deeper aquifer.

Reference: Illinois Environmental Protection Agency files.

CASE HISTORY 41

Location: Springfield, Illinois.

Contaminant: Gasoline.

Source of contamination: Leaking storage tanks suspected.

Effect on the environment: Both soil and ground water were contaminated.

Background: Complaints of gasoline vapors in basements led to an investigation that revealed gasoline was present in sewer lines, soil, and ground water in the area. It was suspected that gasoline was leaking from buried storage tanks. Several borings were made in the area to determine the extent of ground-water contamination and possible sources. At least two wells near an oil company were found to contain gasoline in both soil and water samples.

Geologic setting: Borings to 20 feet in the area revealed the surficial deposits were Peoria Loess over Roxanna Silt. The unconfined water table is present at a depth of 4 to 8 feet.

Remedial action and effectiveness: None reported.

References: Illinois State Geological Survey files and Illinois Environmental Protection Agency files.

CASE HISTORY 42

Location: Macomb, Illinois.

Contaminant: Leachate.

Source of contamination: Landfill.

Effect on the environment: Surface water is contaminated. Ground water also may be affected.

Background: Shortly before a landfill was closed in 1971, leachate was discovered coming from the side of the fill. The continued leachate discharge has led to the conjecture that a spring was buried in the course of landfill operation. Leachate moves toward the La Moine River.

Geologic setting: The area is underlain by relatively fine-grained glacial drift, which becomes coarser with depth. Ground-water movement is toward the La Moine River.

Remedial action and effectiveness: The city of Macomb tried to stop the leachate discharges by regrading the site, with some success. However, final cover has not been placed on the landfill to reduce infiltration.

Reference: Illinois Environmental Protection Agency files.

CASE HISTORY 43

Location: Palos Hills, Illinois.
Contaminant: Leachate.
Source of contamination: Landfill.
Effect on the environment: Ground water of the shallow sand and gravel aquifer was contaminated southwest of the landfill. The extent of the contamination was not determined.
Background: When landfill operations were begun in a sand and gravel quarry, disposal was directly into water at the base of the quarry. Concern about possible ground-water contamination led to an investigation. It was determined that the sand and gravel aquifer was contaminated, but there was no evidence that the underlying limestone aquifer was affected.
Geologic setting: A shallow, unconfined, sand and gravel aquifer of unknown thickness overlies limestone bedrock. Ground-water movement is southwest toward the Des Plaines River.
Remedial action and effectiveness: A 1972 Illinois Pollution Control Board ruling against the landfill required diversion of surface water, installation of a clay liner in places, closure within a year, and continued monitoring. The site has been closed and final cover is nearly complete.
Reference: Illinois Environmental Protection Agency files.

CASE HISTORY 44

Location: South Beloit, Illinois.
Contaminant: Leachate.
Source of contamination: Landfill.
Effect on the environment: At least two monitoring wells and several private wells were contaminated.
Background: An investigation by the Illinois Environmental Protection Agency of a landfill for which a permit application had been received disclosed ground-water contamination as a result of the landfill operation. The landfill has been in operation in a sand and gravel quarry since 1946, and several private wells had become contaminated several years ago.
Geologic setting: The landfill is situated in an abandoned sand and gravel quarry. Ground-water movement within the shallow sand and gravel aquifer is to the south.
Remedial action and effectiveness: The landfill site is closed and monitoring of ground water has been started.
Reference: Illinois Environmental Protection Agency files.

CASE HISTORY 45

Location: Rock Island, Illinois.
Contaminant: Leachate.
Source of contamination: Landfill.
Effect on the environment: Ground water was contaminated.
Background: A landfill operation began in 1955 in a swampy area on the floodplain of the Rock River. Contamination of monitoring wells was detected in late 1972.
Geologic setting: The site is underlain by sand in the Rock River floodplain. Ground-water flow within the shallow sand aquifer is toward the confluence of the Rock and Mississippi Rivers.
Remedial action and effectiveness: None reported. The city of Rock Island has been denied a permit for continued use of the site. The case is in litigation. City officials have begun to look for another site. The existing landfill will probably be closed when a new site is found.
Reference: Illinois Environmental Protection Agency files.

CASE HISTORY 46

Location: Geneseo, Illinois.
Contaminant: Leachate.
Source of contamination: Landfill.
Effect on the environment: Ground-water contamination has not been detected and may be limited to the zone within the fill area.
Background: Dumping was begun at the site before 1900. At about the same time, springs east of the site were tapped as a source of water for Geneseo. Increased demand for water has resulted in the installation of several wells in the landfill area; the springs have been abandoned. Water-quality analyses of the springs and wells during the past several decades has indicated no ground-water contamination beyond the limits of the fill. A change in quality of raw water was first throught to have resulted from pollution by the landfill, but the changes may have been due to increased production from a new aquifer containing water of a poor quality.
Geologic setting: The site is predominantly underlain by sand, accompanied by some interbeds of till, silt, and gravel. The unconsolidated sediments are generally between 50 to 100 feet thick. Regional ground-water movement in the shallow, unconfined sand aquifer is to the north, toward the Illinois and Mississippi Canal. Locally, ground-water flow is toward the water-supply wells south and east of the landfill.
Remedial action and effectiveness: The site was closed in 1974 as a threat to local water-supply wells. The springs and some wells have been abandoned because of deterioration in the quality of the water. However, there has been no conclusive evidence that the landfill is responsible for the degradation, even though the geologic setting is undesirable for landfill operations.
Reference: Illinois State Geological Survey files.

CASE HISTORY 47

Location: Kokomo, Indiana.
Contaminant: Chromates.
Source of contamination: Land disposal of wastes.
Effect on the environment: Two private wells became contaminated.
Background: A private well was contaminated with a creosote-like waste. A new well was drilled near

by that also became contaminated. An investigation revealed that molding sand used in the manufacturing of chrome steel castings had been used for land fill. Water seeping through the sand leached out chromate and carried it through a drainage ditch to a swamp that acted as a recharge zone to ground water. The swamp is close to the affected wells.

Geologic setting: A thin mantle of glacial drift overlies highly jointed and creviced limestone. The limestone is the local source of water.

Remedial action and effectiveness: None reported.

Reference 33.

CASE HISTORY 48

Location: Eklhart, Indiana.

Contaminant: Oil.

Source of contamination: Unknown.

Effect on the environment: Three municipal wells were contaminated.

Background: In the fall of 1956, complaints were made of contamination of a municipal water supply. An investigation revealed that three closely spaced dug wells contained oil. No source was identified, but numerous oil storage tanks were in the area.

Geologic setting: The wells obtain water from a shallow, unconfined sand and gravel aquifer about 50 feet thick. The sand and gravel overlie a clay unit that acts as an aquitard.

Remedial action and effectiveness: One dug well was pumped to waste to prevent further contamination of the well field. The areas of water flooding were increased to maintain higher levels in the aquifer. This program was apparently successful. One contaminated well was put back in partial operation. Some oil still persists.

Reference 33.

CASE HISTORY 49

Location: Madison, Wisconsin.

Contaminant: Leachate.

Source of contamination: Olin Avenue sanitary landfill.

Effect on the environment: Surface water and ground water were contaminated. Contamination does not extend far beyond the edge of the landfill.

Background: A study of two landfills was initiated in 1967 by Robert Kaufmann. One of the purposes of the research was to define the nature and extent of ground-water contamination from the Olin Avenue landfill.

Geologic setting: The landfill site is a former marsh. A dark gray, organic clayey silt 10 to 20 feet thick is present over much of the area beneath a thin peat layer. A clay layer underlies the silt. Varved clay is present in places at depths of 9 to 35 feet. The glacial drift is thin in some areas and is underlain by the Franconia Sandstone (Cambrian). The presence of the landfill has partially converted a ground-water discharge zone to a recharge zone. Most ground-water movement is toward Wingra Creek.

Remedial action and effectiveness: None reported. Kaufmann recommended installation of a leachate collection system and continued monitoring.

Reference 34.

CASE HISTORY 50

Location: Madison, Wisconsin.

Contaminant: Leachate.

Source of contamination: Truax Field sanitary landfill.

Effect on the environment: Surface water and ground water were contaminated. Contamination does not extend far beyond the edge of the landfill.

Background: A study of two landfills was initiated in 1967 by Robert Kaufmann. One of the purposes of the research was to define the nature and extent of ground-water contamination from Truax Field landfill.

Geologic setting: The landfill is underlain by about 25 feet of silty sand and silt. Organic silt and clay are present locally. Glacial deposits are up to 260 feet thick in this area. The presence of near-by high-yield wells has modified the ground-water flow pattern in this area.

Remedial action and effectiveness: None reported. Kaufmann recommended continued ground-water monitoring.

Reference 34.

CASE HISTORY 51

Location: Islip, Long Island, New York.

Contaminant: Leachate.

Source of contamination: Landfill.

Effect on the environment: A leachate plume flows for 5000 feet along a hydrologic boundary near the bottom of the aquifer. The plume is elongate and narrow.

Background: An investigation was made to determine the extent of suspected ground-water contamination thought to be associated with a landfill that had been in operation for 41 years.

Geologic setting: The site is underlain by a shallow glacial aquifer consisting of coarse sand with streaks of gravel and fine sand. The aquifer is 170 feet thick. It is underlain by fine sand and silt that reduce permeability.

Remedial action and effectiveness: None reported.

Reference 35.

CASE HISTORY 52

Location: Babylon, Long Island, New York.

Contaminant: Leachate.

Source of contamination: Landfill.

Effect on the environment: Ground water was contaminated. A long, narrow leachate plume completely penetrates the aquifer, extending 10,600 feet from the landfill. One public supply well was affected.

Background: An investigation was made of the extent of possible ground-water contamination.

Geologic setting: The affected shallow aquifer consists of coarse sand with streaks of gravel and fine sand. This unconfined aquifer is 70 feet thick and is underlain by 12 feet of clay. Ground-water movement in the shallow aquifer was estimated at 2 feet per day.

Remedial action and effectiveness: Pumpage of the affected public water supply well was cut back.

Reference 35.

CASE HISTORY 53

Location: Greensburg oil field, Kentucky.
Contaminant: Chlorides.
Source of contamination: Impoundment.
Effect on the environment: Many shallow wells were affected throughout a large area. Both surface water and ground water were contaminated.
Background: The discovery of the Greensburg oil field in the late 1950s resulted in heavy drilling. Large quantities of brine were produced. At first, the brine was discharged to streams and later to sinkholes and evaporation pits that fed ground water.
Geologic setting: Most homes in the area obtain water from springs or shallow wells. Oil is obtained from a deeper aquifer in the Laurel Dolomite (Silurian) at 400 to 700 feet.
Remedial action and effectiveness: Some effort was made to enforce antipollution laws. The decline of the oil field reduced the contamination.
Reference 36.

CASE HISTORY 54

Location: Monroe County, Michigan.
Contaminant: Leachate.
Source of contamination: Landfill.
Effect on the environment: Ground-water contamination is limited to the area beneath the landfill site.
Background: An investigation was made to evaluate existing and potential pollution resulting from the landfill.
Geologic setting: The site is underlain by about 48 feet of glacial drift. The glacial deposits consist of brown silty clay with sand lenses underlain by silty clay till containing coarse material locally. A thick carbonate aquifer, primarily Silurian dolomite, underlies the drift. The water table is near the surface throughout the year. Ground-water movement is largely vertical. The presence of springs around the periphery of the landfill suggests that a groundwater mound has developed within the fill.
Remedial action and effectiveness: None reported.
Reference 37.

CASE HISTORY 55

Location: Southeastern Coastal Plain.
Contaminant: Pesticides.
Source of contamination: Land disposal of wastes.
Effect on the environment: Ground water initially showed a high level of contamination, but contamination has dropped off and now fluctuates at low levels.
Background: A private well became contaminated with pesticides in late 1966, shortly after the well was constructed. The contamination was traced to the use of soil for backfill for the well. The soil had been adjacent to an area used for filling and flushing a sprayer for pesticides. As the 40-foot deep well was not properly cased, the surface soil containing adsorbed pesticides moved down the well to the water table.
Geologic setting: The water table is at 18 feet. The soil is a sandy loam.
Remedial action and effectiveness: Some sediment was removed from the bottom of the well.
Reference 39.

CASE HISTORY 56

Location: Missouri.
Contaminant: Hazardous waste—dioxin.
Source of contamination: Land disposal of pollutant.
Effect on the environment: The soil was contaminated. In addition, 63 horses, 12 cats, 5 dogs, and hundreds of wild birds died and several people became sick.
Background: The death of numerous animals at three stables led to an investigation. After 3 years, it was determined that an extremely toxic chemical called dioxin was responsible for the deaths and illness. Dioxin had inadvertantly been mixed with waste oil spread in the riding arenas to control dust. Those animals coming into contact with the contaminated soil died.
Geologic setting: No information given.
Remedial action and effectiveness: Contaminated soil was excavated from the stables and removed to landfills, a highway construction site, and a yardfill.
Reference 40 and personal communication from Robert Robinson of the Missouri Department of Natural Resources.

CASE HISTORY 57

Location: Southeastern Pennsylvania.
Contaminant: Industrial waste—terpene and acids.
Source of contamination: Land disposal of industrial wastes.
Effect on the environment: A shallow, private well became contaminated in the fall of 1970.
Background: A complaint of well contamination was traced to land disposal of about 200 gallons of terpene (a turpentine-related substance) and several thousand gallons of dilute acids by an industry in the summer of 1970.
Geologic setting: Bedrock in the area is fractured schist of the Wissahickon Formation. The affected aquifer is unconfined.
Remedial action and effectiveness: A drilling program and subsequent pumping test verified ground-water movement along rock fractures. A pumping program was initiated in October 1972, with discharge through a carbon filter to a stream. Three wells were pumped to reverse ground-water flow back toward the plant. The pumping program was run continuously for a year and intermittently since then. Water quality has improved substantially. However, ground-water quality is still not at background levels. The house with the contaminated well now uses public water.
Reference: Pennsylvania Department of Environmental Resources files.

CASE HISTORY 58

Location: Southeastern Pennsylvania.
Contaminant: Industrial waste—xylene.

Source of contamination: Land disposal of industrial wastes.
Effect on the environment: Soil and surface water were contaminated; vegetation and aquatic life were adversely affected.
Background: In March 1972, a considerable volume of industrial waste was illegally dumped in a drainage ditch along the Pennsylvania Turnpike. The liquid waste—later identified as xylene—traveled down the ditch, spread across a field, and reached a stream. When fish died the incident came to the attention of regulatory officials.
Geologic setting: The soil is poorly drained and contains a fragipan.
Remedial action and effectiveness: Within a few days after the spill, the affected soil was removed and taken to another site for disposal. The soil was spread in a thin layer and disc-plowed into existing soil. The remedial action appears to have been successful.
Reference: Pennsylvania Department of Environmental Resources files.

CASE HISTORY 59

Location: Southeastern Pennsylvania.
Contaminant: Leachate.
Source of contamination: Landfill.
Effect on the environment: Surface and ground water were contaminated from a landfill operation. Numerous spring discharges contained leachate.
Background: The landfill operation began in the late 1960s. In the early 1970s, leachate springs were noted downslope (west and south) of the landfill. Leachate was apparently moving through joints and along bedding planes, discharging as springs. Some leachate discharges reached surface water.
Geologic setting: Bedrock is fractured argillite of the Triassic Lockatong Formation. Depth to bedrock in most of the landfill area is about 5 feet. Unconfined ground-water flow is along fractures and bedding planes.
Remedial action and effectiveness: A trench was cut into bedrock to collect leachate along the western edge of the landfill. The trench, partially lined, transported the leachate to a concrete-lined lagoon constructed to hold it. A similar leachate collection system was constructed to the south. Leachate springs were greatly reduced by the actions taken.
Reference: Pennsylvania Department of Environmental Resources files.

CASE HISTORY 60

Location: Southeastern Pennsylvania.
Contaminant: Fuel oil.
Source of contamination: Spill.
Effect on the environment: As a result of a spill, fuel oil contaminated surficial material, surface water, and probably ground water.
Background: In March 1972, oil was noted in a stream and traced to the property of a fuel oil distributor. The distributor acknowledged that 2 days earlier an accident resulted in a spill of 300 to 500 gallons of fuel oil. The oil had apparently percolated through the soil and reached a storm drain that discharges to a stream.
Geologic setting: Brown sandy silt is present in the area to a depth of about 20 feet. The water table is at a depth of 10 to 15 feet under unconfined conditions.
Remedial action and effectiveness: An oil collection system was installed in the storm drain to prevent oil from reaching the stream. Within 2 weeks after the spill, two truck loads of contaminated soil were removed and replaced by clean fill. Five monitoring wells were installed between the spill and the stream. No fuel oil was detected in the monitoring wells. The fuel oil continued to discharge from the storm drain for several months but finally stopped. The monitoring was terminated.
Reference: Pennsylvania Department of Environmental Resources files.

CASE HISTORY 61

Location: Southeastern Pennsylvania.
Contaminant: Insecticides.
Source of contamination: Land application of pesticides.
Effect on the environment: One private well became contaminated.
Background: The owner of a private well complained of well contamination in April 1972. The contamination was traced to the injection of 100 gallons of dilute insecticide into the soil surrounding the house. Apparently the insecticide moved through the soil to bedrock and along fractures to the water table.
Geologic setting: Fractured diabase bedrock is encountered at a shallow depth. Ground water is unconfined.
Remedial action and effectiveness: The regulatory agency immediately began sampling the contaminated well and near-by wells. Sampling continued until the insecticides were no longer found in the samples—about a year.
Reference: Pennsylvania Department of Environmental Resources files.

CASE HISTORY 62

Location: Southeastern Pennsylvania.
Contaminant: Leachate.
Source of contamination: Landfill.
Effect on the environment: Shallow ground-water contamination was detected in monitoring wells between the landfill and a near-by stream.
Background: Samples from monitoring wells showed ground-water contamination. The wells are immediately down-gradient from the landfill in the direction of a stream about 50 to 100 feet away. The refuse had been placed against the quarry wall. Apparently some refuse had been placed in water at the base of the quarry when landfill operations began.

Geologic setting: The landfill is in an abandoned rock quarry of granite gneiss. The gneiss is well jointed. Shallow ground-water movement is toward the stream.

Remedial action and effectiveness: The site has been covered and closed. A leachate collection system may be installed.

Reference: Pennsylvania Department of Environmental Resources files.

CASE HISTORY 63

Location: Southeastern Pennsylvania.

Contaminants: Leachate, chemical wastes.

Source of contamination: Improper waste disposal.

Effect on the environment: Surface and ground water were contaminated.

Background: Contamination of surface water led to an investigation. The suspected source was an abandoned landfill, which is on property now owned by a chemical company. An investigation was made to determine the extent of ground-water contamination and the feasibility of ground-water clean-up. The study showed that poor housekeeping by the chemical company and improper waste disposal were major contributors to surface- and ground-water contamination. The degradation caused by the landfill was less severe.

Geologic setting: The static water level is within a few feet of the surface.

Remedial action and effectiveness: The case was reported to be still in litigation.

Reference: Pennsylvania Department of Environmental Resources files.

CASE HISTORY 64

Location: Southeastern Pennsylvania.

Contamination: Hazardous industrial wastes.

Source of contamination: Land disposal of wastes.

Effect on the environment: An investigation revealed evidence of soil, surface-water, and possibly ground-water contamination.

Background: In early 1973 the Pennsylvania Department of Environmental Resources discovered an illegal disposal area in which various hazardous wastes were dumped. An investigation showed numerous drums and barrels on the property, some of them buried. Spillage was common. A lagoon was present on the site containing hazardous wastes, including heavy metals. Vegetation was dead as a result of an overflow from the lagoon.

Geologic setting: The site is underlain by diabase of Triassic Age.

Remedial action and effectiveness: Some effort has been made to remove some of the drums and eliminate sources of contamination. No action has been taken to determine the extent of contamination.

Reference: Pennsylvania Department of Environmental Resources files.

CASE HISTORY 65

Location: Southeastern New Mexico.

Contaminant: Chlorides—oil-field brine.

Source of contamination: Brine disposal pit.

Effect on the environment: Shallow ground water was contaminated in a narrow band down-gradient from a brine disposal pit.

Background: Leakage of salt water from a brine disposal pit was determined to be the source of ground-water contamination. Chloride concentrations increased with depth in the aquifer because the salt water was denser than native ground water.

Geologic setting: The site is underlain by the Ogallala Formation, which consists of fine- to medium-grained sand. A gravel interval is present near the base. The formation is about 230 feet thick. It is underlain by a relatively impermeable red shale.

Remedial action and effectiveness: Water was pumped from a large-diameter well and was used for secondary oil recovery by waterflooding deep aquifers. About 50.4 million gallons of water was pumped in 20 months. Water quality has improved significantly.

Reference 41.

CASE HISTORY 66

Location: Dover Township, New Jersey.

Contaminant: Industrial wastes—petrochemicals.

Source of contamination: Land disposal of wastes.

Effect on the environment: Many shallow wells were contaminated within a 1-mile radius of the disposal site.

Background: In early 1974, numerous citizens began complaining of well contamination. After some investigation, the ground-water contamination was traced to the illegal dumping of several thousand drums of petrochemicals, apparently by a trucker. The petrochemicals had leached from the drums to ground water.

Geologic setting: The surface deposit is fine to coarse sand of the Cohansey Formation, including some gravel streaks and discontinuous clay lenses. It varies from 50 to over 100 feet thick. Most of the affected wells were completed in the Cohansey Formation. The underlying unit, the Kirkwood Formation, consists of about 80 feet of sand. A few wells finished in the upper portion of the Kirkwood Formation were affected.

Remedial action and effectiveness: At a meeting of local, state, and Federal officials in August 1974, the contaminated wells were declared unsafe. Carbon filters were recommended as an interim measure. An alternative water supply for the area was considered. A program was developed to determine the extent of ground-water contamination. The drums of petrochemicals were removed. Some thought was given to recovering ground water, treating it, and recharging the treated ground water at the edge of the zone of contamination to flush out the remaining contaminants. It was determined that such treatment would be too expensive and time-consuming.

Reference: Personal communication from Frank Markewicz of the New Jersey Department of Environmental Protection.

CASE HISTORY 67

Location: New Jersey.

Contaminant: Industrial waste—heavy metals, including chromium, zinc, and copper.

Source of contamination: Impoundments.

Effect on the environment: Ground-water contamination affected the upper 30 feet of an unconfined aquifer.

Background: The problem was caused by leakage from industrial lagoons. It was estimated several hundred million gallons of ground water were contaminated. Surface water and the deeper aquifers were threatened.

Geologic setting: A shallow water-table aquifer is present. Deeper aquifers are heavily pumped.

Remedial action and effectiveness: All the industrial lagoons were lined with concrete. Several shallow wells were installed between the lagoons and a stream, and they are pumped to contain the zone of ground-water contamination. Water is treated prior to discharge. Pumping was not expected to remove the pollutants effectively because ground-water movement is slow, and the ground water will be contaminated for some time to come. However, the zone of contamination has been restricted.

Reference 42.

CASE HISTORY 68

Location: Southern Connecticut.

Contaminant: Leachate.

Source of contamination: Landfill.

Effect on the environment: Both surface and ground water were contaminated. An estimated 80,000 gallons of leachate form in the landfill each day. The zone of ground-water contamination was approximately 3500 feet by 3000 feet by 60 feet.

Background: A study was made to determine whether a landfill was causing ground-water contamination. Up to 30 feet of refuse had been placed in a wetland area covering 90 acres during a period of 30 years.

Geologic setting: The site is underlain by 40 to 60 feet of generally unsorted glacial sands and silts that rest on bedrock. The water table was originally near the surface, but it rose 8 feet into the refuse as a result of the landfill operation.

Remedial action and effectiveness: The investigation included drilling, sampling of water, and geophysical studies. The information gained during the study prompted the recommendation that the landfill be closed. An attempt will be made to regrade the landfill and to add a cover of relatively impermeable material to minimize infiltration.

Reference 42.

CASE HISTORY 69

Location: Canyon Creek Basin (near Coeur D'Alene), Idaho.

Contaminant: Hazardous mine wastes containing cadmium, lead, and zinc.

Source of contamination: Impoundment construction.

Effect on the environment: Ground water and surface water were contaminated.

Background: Tailings from old mines worked between the 1880s and 1930s were dumped by the miners onto the alluvial plain of Canyon Creek. In 1968, two tailings ponds were installed in the alluvium. Construction of the settling ponds apparently raised water levels in the alluvium and in down-gradient wells. This exposed more mine tailings in the alluvium to chemical action, increasing the concentrations of heavy metals in ground water.

Geologic setting: The site is on the alluvial plain of Canyon Creek. The alluvial deposits (mostly sand and gravel) are underlain by Precambrian rocks of the Belt Series. The water table is shallow.

Remedial action and effectiveness: The mining company dug trenches between 3 and 14 feet deep that lowered the water table 1 to 4 feet. This may have some effect, but further action may be necessary.

Reference 43.

CASE HISTORY 70

Location: Ames, Iowa.

Contaminant: Leachate.

Source of contamination: Landfill.

Effect on the environment: Ground water was contaminated in a zone extending 7000 feet down-gradient from the landfill and to a vertical depth of between 80 and 100 feet.

Background: In 1972, an investigation was made to determine whether a landfill was causing contamination and, if so, to what extent. The landfill is 18 years old and covers 34 acres.

Geologic setting: Refuse was placed in 4 to 12 feet of silt and clay that overlies alluvial sand and gravel in a buried bedrock valley. The site is on the floodplain of the Skunk River. Ground-water movement is southwest at an acute angle to the Skunk River, which flows south. The shallow aquifer is unconfined.

Remedial action and effectiveness: None reported.

Reference 45.

CASE HISTORY 71

Location: Omaha, Iowa.

Contaminant: Leachate.

Source of contamination: Landfill.

Effect on the environment: Ground water is contaminated in a zone 5100 feet wide, 670 feet long (truncated by the Missouri River), and 40 feet deep. The bottom of the contaminated zone coincides with the bedrock surface.

Background: Beginning in 1972, an investigation was made of the extent of possible ground-water contamination associated with the Omaha landfill. The landfill is 9 years old and covers 110 acres.

Geologic setting: The site is on the floodplain of the Missouri River, situated in 3 to 30 feet of silt and clay that overlies fine sand and silt lenses within a buried bedrock valley. Ground water moves southwest toward the Missouri River. There is some recharge of the aquifer by the river.

Remedial action and effectiveness: None reported.

Reference 45.

CASE HISTORY 72

Location: Ohio.

Contaminant: Chlorides.

Source of contamination: Improper disposal of wastes.
Effect on the environment: Four wells in a well field were contaminated.
Background: Chlorides in a municipal well field began to increase dramatically in late 1953. An investigation revealed that a near-by water-treatment plant had been discharging concentrated salt brine into a dry ditch 850 feet from the nearest well. The brines were recharging the well field.
Geologic setting: Gravel is present at shallow depths. No other geologic information was provided.
Remedial action and effectiveness: Three steps were taken to correct the problem. (1) A new drain was installed to carry the brine to the river. (2) The well most affected was pumped to waste to the river for 2 years. (3) A large pit was dug (100 by 30 by 20 feet) in the gravel, and river water was used to recharge the aquifer. This approach seems to have solved the problem. Chloride concentrations have dropped to nearly background levels.
Reference 46.

CASE HISTORY 73

Location: Nassau County, New York.
Contaminant: Plating wastes—hexavalent chromium and cadmium.
Source of contamination: Impoundment.
Effect on the environment: A plume of ground-water contamination extended about 4000 feet to Massapequa Creek. The plume is up to 1000 feet wide and as much as 70 feet thick. Contamination thus far has been limited to the upper of two aquifers.
Background: A survey by the Nassau County Department of Health in 1942 revealed a well with a high concentration of chromium. The affected well was near a metal-plating operation. The contamination was traced to three unlined disposal basins for plating wastes, which had been put into operation in 1941. An estimated 200,000 to 300,000 gallons of plating wastes were discharged daily in the 1940s.
Geologic setting: The surficial aquifer consists of fine to coarse sand and gravel. The aquifer is unconfined, and it is this aquifer that is affected by the plating wastes. The disposal basins are just above the water table, which may periodically intersect the base of the basins. Ground-water flow is toward Massapequa Creek. A discontinuous silty and sandy clay interval at the base of the aquifer separates it from an underlying confined aquifer.
Remedial action and effectiveness: A waste-treatment plant for chromium wastes was completed in 1949. Several wells have been used since that time to define the extent and movement of the contaminant. The volume of wastes has been reduced. Ground-water contamination is still present, but concentrations of chromium in ground water have dropped from about 40 to less than 5 mg/l since the start of the treatment system in 1949.
Reference 47.

CASE HISTORY 74

Location: Morrow County, Ohio.
Contaminant: Oil-field brine.
Source of contamination: Disposal pits.
Effect on the environment: A shallow well became contaminated in 1967. Chloride concentrations of up to 7700 mg/l were measured. A near-by stream was also affected.
Background: Shallow well contamination was traced to several "evaporation" pits that formerly had existed in the area for disposal of oil-field brines; one was only 600 feet away. The pits had been installed in 1964 and 1965, and were reportedly abandoned and filled by late 1965.
Geologic setting: No information given.
Remedial action and effectiveness: At one point, an oil company pumped the contaminated well for about 3 days to clear up the well. It got worse. No other action was reported.
Reference 48.

CASE HISTORY 75

Location: Delaware County, Ohio.
Contaminant: Chlorides—oil field brine.
Source of contamination: Disposal pits suspected.
Effect on the environment: Shallow ground water was contaminated in an area about 1200 by 500 feet; the area was bounded on three sides by streams.
Background: Three oil wells had been drilled in this area and four brine evaporation pits had been created in 1964 and 1965. Ground-water contamination was suspected.
Geologic setting: The site is on the floodplain of the Olentangy River. The surficial deposits consist of 15 to 35 feet of alluvial and glacial gravel interbedded with sand, silt, and clay.
Remedial action and effectiveness: No action was reported. Chloride concentrations have decreased with time as a result of normal flushing. However, this reduction is not a linear relation. Salt is apparently tied to the clay and silt and is released during infiltration.
Reference 48.

CASE HISTORY 76

Location: Bellevue, Ohio.
Contaminant: Sewage.
Source of contamination: Improper waste disposal.
Effect on the environment: Numerous wells were contaminated in a zone 5 miles wide and 15 miles long extending toward Lake Erie.
Background: Wells in the vicinity of Bellevue have been polluted for some time. The aquifer is contaminated as a result of widespread, long-term disposal of sewage and other wastes down wells and into sinkholes.
Geologic setting: The site is underlain by a highly permeable limestone aquifer. Sinkholes are common in the area.
Remedial action and effectiveness: A sewage treatment plant was built in 1971. No other reported action.
Reference 49.

CASE HISTORY 77

Location: Eastern Ohio.
Contaminant: Industrial waste—neutralized spent pickling liquors.

Source of contamination: Improper disposal of wastes.

Effect on the environment: A stream east of the disposal area was seriously polluted. Two fish kills were reported. Ground water also was contaminated.

Background: Sludge was deposited in a pit in a strip-mined area after a geologic evaluation indicated there would be no ground-water pollution problem. Disposal began in 1964. Complaints of surface-water contamination began in February 1966. Apparently some acid wastes were disposed of without treatment. In 1970 the pit was widened and deepened to make room for more wastes. More severe water-quality problems soon became apparent.

Geologic setting: The site is underlain by rocks of Pennsylvanian age, which include beds of sandstone, shale, coal, and underclay.

Remedial action and effectiveness: An agreement was reached in late 1973 to build a plant and other facilities to treat and contain the wastes discharging into a stream.

Reference 50.

CASE HISTORY 78

Location: Keizer, Oregon.

Contaminant: Industrial waste.

Source of contamination: Impoundment.

Effect on the environment: Several shallow wells were contaminated.

Background: In late 1946 residents with shallow domestic wells complained of well contamination. The contamination was traced to disposal of industrial wastes into a borrow pit for a period of about 1 year. Aluminum ore and mine tailings treated with sulfuric acid and ammonium hydroxide had been dumped into the borrow pit and the resultant leachate had then entered the ground water.

Geologic setting: The site is underlain by an unconfined aquifer that consists of about 50 feet of moderately to highly permeable alluvial deposits. The water table is at a depth of about 10 to 20 feet. Ground-water movement is estimated at 4.5 feet per day to the northwest, toward the Willamette River.

Remedial action and effectiveness: The waste was removed from the borrow pit in the spring of 1948. Two wells were drilled near the pit and pumped heavily for several months. Both wells had a reported yield of more than 700 gpm. By 1964 the contamination had been greatly reduced by dilution and pumping.

Reference 52.

CASE HISTORY 79

Location: Near Cumberland, Maryland.

Contaminant: Phenol.

Source of contamination: Spill.

Effect on the environment: Surface water and soil were contaminated. Downstream water supplies were threatened.

Background: A train overturned on June 27, 1972, and spilled 25, 000 gallons of phenol on the ground. Officials estimated that 166, 000 pounds of phenol remained in the vicinity of the spill, infiltrating the soil. About 10, 000 pounds went to a stream.

Geologic setting: No information given.

Remedial action and effectiveness: Soil samples were taken at depths of up to 3 feet to determine the extent of contamination. Three actions were then considered. (1) Use of flamethrowers to burn the top 3 inches of soil and render the phenol harmless. Rejected as a fire hazard. (2) Removal of the top 6 inches of soil and addition of fresh soil. The contaminated soil was to be spread on the land. Rejected because of cost. (3) Construction of a carbon treatment plant to remove phenol from runoff water. This approach was accepted. By May of 1973, phenol concentrations in the soil were much reduced. The treatment plant was shut down October, 1973.

Reference 53.

CASE HISTORY 80

Location: Massillon, Ohio.

Contaminant: Industrial waste.

Source of contamination: Improper waste disposal.

Effect on the environment: The Tuscarawas River and shallow ground water were contaminated as a result of induced infiltration into the permeable sand and gravel aquifer.

Background: When public water-supply wells became contaminated, the contamination was traced to the discharge of by-products from an industrial glass plant to the river. The problem developed when the river was diverted to run over a more permeable bed. The water-supply wells near the river induced infiltration of river water to the wells.

Geologic setting: Sand and gravel aquifers adjacent to the river yield as much as 2000 gallons of water per minute.

Remedial action and effectiveness: The industry will shut down in 1977 as a result of new state water-quality standards. New sources of ground water are being sought away from the river.

Reference 54.

CASE HISTORY 81

Location: Mechanicsburg, Pennsylvania.

Contaminant: Gasoline.

Source of contamination: Unknown.

Effect on the environment: Gasoline was found floating on the water table to a depth of as much as 4 feet in an area measuring a third of a square mile.

Background: Gasoline was detected by a local businessman during drilling of an illegal well in February 1969. An investigation was made and all tanks in the area were tested for leaks; no leaks were found. The exact source was never identified, but the gasoline must have come from one or more of the three areas where petroleum products were stored or from two petroleum pipelines in the area. More than 250, 000 gallons of gasoline were estimated to have been lost.

Geologic setting: The site is underlain by limestone of the Rockdale Run Formation (lower Ordovician). A dominant vertical joint set is present. The water table is shallow.

Remedial action and effectiveness: A well was drilled to pump out the gasoline. About 55,000 gallons were recovered in 1 month before pumping was terminated. The problem was rediscovered 3 months later by the Highway Department while borings were being made. The oil companies in the area began drilling other wells to remove the gasoline. This met with some success until a heavy rain brought the water table to the surface. Gasoline fumes in two cellars caused minor explosions. As a result of the explosions, a task force was set up to (1) define the contaminated area, (2) remove gasoline, and (3) insure that there would be no further leakage. Over 40 wells were drilled, particularly along fracture traces. Between 1969 and 1971, a total of 216,000 gallons of gasoline was recovered by pumping. Recovery was generally best when the water table was low. However, the water table responds dramatically to precipitation, rising to the surface and hindering recovery. Removal is continuing by pumping, skimming, and the use of absorbents. Although the program has been effective, further recovery has become more difficult.

References 55 and 56.

CASE HISTORY 82

Location: Rensselaer County, New York.

Contaminant: Industrial waste—formaldehyde solution.

Source of contamination: Spill.

Effect on the environment: Soil contamination resulted from a spill. However, the soil absorbed formaldehyde and limited the area of contamination to 100 feet by 25 feet. Some contamination of ground water occurred. A near-by stream was not significantly affected.

Background: On June 6, 1972, a truck overturned and spilled 5000 gallons of formaldehyde solution.

Geologic setting: The soil is a sandy loam. The water table is near the surface. A marsh and unnamed stream are approximately 150 feet from the spill site.

Remedial action and effectiveness: Samples of soil, ground water, surface water, and stream sediment showed soil and ground-water contamination. No remedial action was taken. Little contamination was noticeable after a year.

Reference 57.

CASE HISTORY 83

Location: Brokaw, Wisconsin.

Contaminant: Industrial waste—spent sulfite liquor.

Source of contamination: Impoundment.

Effect on the environment: Surface and ground water were contaminated.

Background: A paper company stored spent sulfite liquor in a pond for about 4 years. It was hoped that the quality of the polluted water would be improved as it moved through the soil. However, an investigation revealed both surface- and ground-water contamination.

Geologic setting: No information given.

Remedial action and effectiveness: Initially, a high-capacity well was used to withdraw contaminated ground water from the aquifer, and a barrier well was used to contain the spread of contaminants. Ground water was discharged to the Wisconsin River. Two more pumping wells and four more barrier wells were installed later. The remedial action has contained the zone of contamination but is not as effective as anticipated. Pumping will be necessary for a long time to fully renovate the aquifer.

Reference 58.

CASE HISTORY 84

Location: Ripon, Wisconsin.

Contaminant: Organic wastes.

Source of contamination: Improper disposal of waste.

Effect on the environment: Two industrial supply wells were contaminated.

Background: Contamination of a canning company well led to an investigation. The contamination was traced to improper handling of the canning company's own wastes.

Geologic setting: Limestone and sandstone aquifers are present at shallow depths.

Remedial action and effectiveness: The contaminated well was initially pumped to remove the contaminants, with little success. The well was abandoned and sealed. Increased use of a high-capacity well resulted in contamination of that well also. It was pumped and treated with limited effectiveness. It was finally deepened, and used with another deep well to supply water for the cannery. No further problems have developed.

Reference 58.

CASE HISTORY 85

Location: Fond du Lac County, Wisconsin.

Contaminant: Organic wastes.

Source of contamination: Improper disposal of waste.

Effect on the environment: Surface water and ground water were contaminated. At least one well was affected.

Background: In 1964, the Wisconsin State Board of Health received complaints of ground-water contamination. An investigation suggested that organic wastes from a pea cannery were adversely affecting ground water, but no definite proof was found.

Geologic setting: Gravel is present above limestone bedrock. No other information was given.

Remedial action and effectiveness: The contaminated well was abandoned and sealed. The canning company lined a disposal pit to collect the silage liquor for proper disposal. The effectiveness of this action is not known.

Reference 58.

CASE HISTORY 86

Location: Onalaska, Wisconsin.

Contaminant: Industrial wastes.

Source of contamination: Impoundments.

Effect on the environment: At least three private wells were contaminated.

Background: Investigations were undertaken by the state of Wisconsin between 1966 and 1968. At least three

private wells were found to be polluted by waste water leading from several near-by impoundments. The 200,000 gallons of waste produced daily contain high concentrations of chlorides, fluorides, sulfates, and trace amounts of metallic ions.
Geologic setting: No information given.
Remedial action and effectiveness: Treatment of the wastes was provided prior to infiltration. A new well was drilled to replace affected wells.
Reference 58.

CASE HISTORY 87

Location: Beloit, Wisconsin.
Contaminant: Gasoline.
Source of contamination: Unknown.
Effect on the environment: At least seven wells were contaminated.
Background: In 1969, the Wisconsin Department of Natural resources received a complaint of well contamination in Beloit. At least seven wells contained gasoline. Several gasoline stations were located some 3000 feet up-gradient from the affected wells. However, sampling failed to identify the source of the gasoline.
Geologic setting: The polluted wells were finished in sand and gravel deposits at depths of 64 to 84 feet. No other information was given.
Remedial action and effectiveness: None reported.
Reference 58.

CASE HISTORY 88

Location: Sussex, Wisconsin.
Contaminant: Petroleum products.
Source of contamination: Storage tank leak suspected.
Effect on the environment: Surface and ground water were contaminated. At least eight wells contained petroleum products.
Background: In 1971, complaints that water from some wells tasted and smelled like petroleum led to an investigation by the Wisconsin Department of Natural Resources. Eight wells were found to contain petroleum products. In addition, oil was found entering a stream. Although the source was never positively identified, it was suspected that several buried gasoline storage tanks that had been abandoned were responsible.
Geologic setting: The fractured Niagaran Series, largely limestone, underlies a thin glacial drift cover. The limestone is a major aquifer in the area.
Remedial action and effectiveness: Remedial action was reported to be pending.
Reference 58.

CASE HISTORY 89

Location: Genesee, Wisconsin.
Contaminant: Sewage.
Source of contamination: Improper disposal of wastes.
Effect on the environment: Ground water was contaminated in at least 20 private wells.
Background: Because of intermittent well contamination, the state of Wisconsin conducted a well-sampling survey in Genesee in 1970. The contamination was thought to result from improper disposal of sewage in an unfavorable geologic setting.
Geologic setting: The area contains a thin glacial drift cover overlying fractured Niagaran dolomite. Most wells are finished in the dolomite.
Remedial action and effectiveness: None reported.
Reference 58.

CASE HISTORY 90

Location: Hanford, Washington.
Contaminant: Radioactive wastes.
Source of contamination: Leaking storage tank.
Effect on the environment: Soil beneath the site contains radioactive wastes. The contaminants have moved as much as 86 feet deep and as much as 150 feet laterally. The contaminants have not reached ground water.
Background: In 1973 the Atomic Energy Commission reported that 115,000 gallons of "high level" radioactive wastes had leaked from a storage tank. Ground water was apparently not affected, but the soil beneath the tank remains radioactive. The Federal Environmental Protection Agency concluded that the contaminants will not move quickly to ground water since precipitation is only about 6 inches per year.
Geologic setting: The water table is from 175 to 335 feet below land surface. Ground-water movement is toward the Columbia River.
Remedial action and effectiveness: None reported.
Reference 59.

CASE HISTORY 91

Location: Not identified.
Contaminant: Leachate.
Source of contamination: Landfill and fly-ash dump.
Effect on the environment: Separate zones of ground-water contamination were identified, one fed by a landfill and one by a fly-ash dump. The zones of contamination were 20 to 60 feet thick.
Background: An investigation was made in the vicinity of a landfill, a fly-ash dump, and a zone of brackish ground water in an attempt to define the extent of suspected ground-water contamination.
Geologic setting: Bedrock of unknown character is encountered at depths of 5 to 90 feet. The static water table is present at a depth of 2 to 28 feet under unconfined conditions.
Remedial action and effectiveness: Thirty-six wells were installed in the area to determine the subsurface geology, ground-water conditions, and water quality. Resistivity measurements were also made to evaluate their usefulness in defining ground-water contamination. No known action was taken to remedy the ground-water contamination.
Reference 60.

CASE HISTORY 92

Location: Not stated.
Contaminant: Industrial waste.
Source of contamination: Unknown.
Effect on the environment: Ground water was contaminated.
Background: Wells on a plant property became contaminated. The contamination was traced to the disposal of industrial waste on the property.

Geologic setting: The surficial material consists of highly permeable sands and gravel, some silt, and thin lenses of clay. The static water level is at about 20 feet under unconfined conditions. The aquifer is 15 to 35 feet thick.

Remedial action and effectiveness: The extent of ground-water contamination was outlined by resistivity measurements. Existing wells were used to confirm the results. No further action was reported.

Reference 60.

CASE HISTORY 93

Location: Not identified.

Contaminant: Industrial waste.

Source of contamination: Impoundment.

Effect on the environment: Several wells on an industrial property became contaminated. The plume of contamination was 10 to 20 feet thick.

Background: The contamination was traced to several holding ponds on plant property.

Geologic setting: The surficial deposits are predominantly clay to the west and grade to sand to the east. They grade to clay at 20 to 40 feet deep. The shallow, unconfined aquifer is encountered at a depth of 1 to 16 feet.

Remedial action and effectiveness: Nineteen vertical electrical soundings and 79 single-depth resistivity measurements were made to define the zone of contamination. An extensive drilling program was undertaken, and water samples from 40 wells were used to confirm the resistivity results. No other action was reported.

Reference 60.

CASE HISTORY 94

Location: Turner, Oregon.

Contaminant: Leachate from wood wastes.

Source of contamination: Improper disposal of waste.

Effect on the environment: Several shallow domestic wells were contaminated. By January 1973, the leachate plume had moved 1500 feet and covered 15 acres.

Background: Several shallow domestic wells became contaminated in the fall of 1972. The contamination was traced to disposal of wood wastes in an abandoned gravel quarry that covered about 2 to 3 acres and was 10 to 12 feet deep. Contact of wood wastes with ground water resulted in leachate that contaminated several shallow wells.

Geologic setting: The site is underlain by alluvium (silt, sand and gravel) to a depth of 50 to 100 feet. Depth to the water table is as much as 10 feet. Ground-water movement is generally to the northwest in the direction of the affected wells. Basalt underlies the alluvium.

Remedial action and effectiveness: A municipal water supply was extended to the affected area to replace the contaminated wells. Ground water remains polluted.

Reference 61.

CASE HISTORY 95

Location: Perham, Minnesota.

Contaminant: Arsenic.

Source of contamination: Land disposal of grasshopper poison.

Effect on the environment: Soil and ground water were contaminated. Ground water contained up to 21,000 parts per billion of arsenic; 50 parts per billion is considered safe. Eleven persons became ill.

Background: A contractor dug a well in 1972. Several employees drank the water and became ill. Interviews with local people disclosed that a bait for killing grasshoppers that contained arsenic had been buried on the site between 1934 and 1936. The disposal site was about 20 feet from the contaminated well at a depth of 7 feet. The well is 31 feet deep.

Geologic setting: The soil is a sandy loam.

Remedial action and effectiveness: A public water supply was installed and use of the well was discontinued. The regulatory agency wants to remove the contaminants. Several procedures have been considered, but because of the cost no action was taken to remove the contaminants. Sampling of nearby wells was continued.

References 62 and 67.

CASE HISTORY 96

Location: Posen, Michigan.

Contaminant: Sewage.

Source of contamination: Septic tanks.

Effect on the environment: Several wells became contaminated and an outbreak of infectious hepatitis resulted.

Background: An outbreak of infectious hepatitis in 1959 was traced to generally poor well construction in the area and to the location of many wells near septic tanks.

Geologic setting: A thin veneer of glacial till (3 feet maximum) is present above bedrock. The glacial till provides little or no renovation of septic tank effluent. Limestone and some shale of the Traverse Group (Devonian) underlie the till. All private wells obtain water from the limestone.

Remedial action and effectiveness: An attempt was made to get a public water supply for the town.

Reference 63.

CASE HISTORY 97

Location: Derby, Colorado.

Contaminant: Industrial waste.

Source of contamination: Impoundments.

Effect on the environment: Several square miles of a shallow aquifer down-gradient from two industrial waste impoundments were contaminated. Several wells were affected.

Background: Damage to crops irrigated with water from shallow wells led to an investigation in 1954. The contamination was traced to disposal of various industrial wastes in two unlined lagoons from 1943 to 1957. Contaminants included chlorates, 2,4-D, and other phytotoxic organic substances.

Geologic setting: The shallow contaminated aquifer consists of alluvium and eolian sand and silt of "Pleistocene and Recent age." The surficial deposits overlie poorly consolidated clastic sediments of Cretaceous and Tertiary ages. These sediments compose the shallow unconfined aquifer. The thickness of the saturated zone ranges up to 50 feet. The shallow aquifer is the only aquifer affected thus far. Deeper aquifers are confined by clay layers. Ground-water flow is toward the South Platte River, 5 to 6 miles away.

Remedial action and effectiveness: All wastes have gone to a lined reservoir since 1957. Samples were taken to determine the extent of contamination. Water was provided for homes with contaminated wells. Consideration was given to treating the wastes and injecting them underground, and also to pumping contaminated ground water to waste to the South Platte River. The zone of ground-water contamination continued to spread.

References 64 and 69.

CASE HISTORY 98

Location: Peoria, Illinois.

Contaminant: Chlorides.

Source of contamination: Salt pile.

Effect on the environment: Ground-water contamination appeared within the cone of depression of several industrial wells.

Background: An investigation was made to determine the source of periodic increases in hardness and chloride content in an industrial well field. The main source of contamination was a salt-storage area for Peoria near the affected wells. Some chlorides probably also reach ground water from a near-by storm sewer, which carries contributions from road salt and industrial wastes containing chlorides.

Geologic setting: The area is underlain by a very permeable sand and gravel aquifer about 60 feet thick. The water table is near the surface. Several industrial and municipal wells have been heavily pumped for some time, creating an elliptical cone of depression that parallels the adjacent Illinois River.

Remedial action and effectiveness: None reported.

Reference 65.

CASE HISTORY 99

Location: Christian County, Illinois.

Contaminant: Sewage.

Source of contamination: Pig feed lots.

Effect on the environment: Two shallow dug wells were contaminated with high nitrate concentrations.

Background: Two dug wells were found to have high nitrate levels. Contamination was traced to pig feed lots about 250 feet away.

Geologic setting: A shallow, unconfined sand and gravel aquifer overlies shale bedrock. Wells are completed in the sand and gravel interval.

Remedial action and effectiveness: The wells were abandoned in 1966, and a new well was drilled up-gradient from the feed lots.

Reference 66.

CASE HISTORY 100

Location: Marshall County, Illinois.

Contaminant: Chemical wastes.

Source of contamination: Leak in sewer line.

Effect on the environment: Two industrial wells for a chemical company became contaminated.

Background: One industrial well, then a second, became contaminated in July 1966. The problem was traced to leaks in a concrete sewer line on the industry's property.

Geologic setting: The wells were finished in a shallow aquifer, presumably sand and gravel.

Remedial action and effectiveness: One of the contaminated wells was pumped to create a cone of depression that would prevent the spread of contaminants. The other well was abandoned and a new well was drilled in an uncontaminated area. The leaks in the concrete sewer lines were found and repaired. The corrective action appears to have been successful.

Reference 66.

CASE HISTORY 101

Location: Along the Illinois River at Creve Coeur, Illinois.

Contaminant: Gasoline.

Source of contamination: Pipeline break.

Effect on the environment: Ground water became contaminated. A municipal well 500 feet from a break in a pipeline was affected.

Background: A break in a buried gasoline transmission line was discovered in the spring of 1957.

Geologic setting: The aquifer consists of sand and gravel.

Remedial action and effectiveness: The pipeline break was repaired within a few hours. However, gasoline persisted in ground water for at least 4 years. Infiltrating rain water continued to flush gasoline to the well.

Reference 66.

CASE HISTORY 102

Location: Across the Illinois River from Peoria, Illinois.

Contaminant: Mineralized waste water.

Source of contamination: Land disposal of waste.

Effect on the environment: Public water-supply wells became contaminated.

Background: Several public water-supply wells became contaminated with highly mineralized water shortly after they were installed. The contamination was traced to near-by surface disposal of waste from a water softener.

Geologic setting: The wells were finished in an unconfined sand and gravel aquifer.

Remedial action and effectiveness: The wells were relocated.

Reference 66.

CASE HISTORY 103

Location: Washington County, Illinois.

Contaminant: Nitrates.

Sources of contamination: Fertilizer, hog lot, septic system.
Effect on the environment: At least one shallow dug well was contaminated.
Background: In a routine check of a shallow dug farm well, the nitrate concentration was found to be 590 mg/l. A drilling and sampling program was undertaken to determine the source of pollution. Three major sources of contamination were noted: inorganic fertilizer spread on the fields, an old hog lot site, and a farm septic system.
Geologic setting: The surficial material consisted of 4 to 6 feet of Peoria Loess overlying 4 to 5 feet of Roxana Silt, which in turn lies over 3 to 4 feet weathered glacial till. Bedrock is Pennsylvanian shale. The water table is at a depth of 1 to 10 feet.
Remedial action and effectiveness: None reported.
Reference 68.

CASE HISTORY 104

Location: Hardeman County, Tennessee.
Contaminant: Pesticides.
Source of contamination: Land disposal of wastes.
Effect on the environment: Soil and ground water were contaminated.
Background: In 1964, a chemical company began burying waste materials from the manufacture of pesticides. Concern was expressed by public health officials regarding possible ground-water contamination, and the U. S. Geological Survey was called in to investigate. Contaminants found in the soil material extended 25 feet laterally from the edge of the disposal area and to a depth of 90 feet (depth to the water table). Contaminated ground water was detected in a perched water zone and in the local water-table aquifer.
Geologic setting: A perched ground-water aquifer and a local water-table aquifer are present. No other geologic information was given.
Remedial action and effectiveness: None reported.
Reference 67.

CASE HISTORY 105

Location: Near Galena, Illinois.
Contaminant: Mining waste—waste water from ore processing.
Source of contamination: Waste disposal to mine.
Effect on the environment: Ground water was contaminated. At least four private wells were affected.
Background: A complaint of well contamination in 1968 led to an investigation. Ore-processing waste water had for some time been discharged to an abandoned lead and zinc mine and had contaminated ground water. The mine was operated between 1947 and 1966, and heavy ground-water pumpage was necessary to permit mining. As a result, the water-table configuration was modified. After the mine closed, a flotation-process ore separation mill continued to operate. Between 1966 and 1968, the waste water from the mill was discharged to the mine, and it contaminated ground water and several near-by wells.
Geolcgic setting: Mining activity and most domestic wells were finished in dolomite of the Galena and Platteville Groups.
Remedial action and effectiveness: Discharge of the ore-processing waste water to the mine was stopped. Those persons whose wells were affected sued the mining company and won damages totaling $69,250.
Reference 67.

CASE HISTORY 106

Location: Minneapolis, Minnesota.
Contaminant: Leachate.
Source of contamination: Landfill.
Effect on the environment: Ground water was contaminated by a landfill operation.
Background: An investigation was made to determine the extent of possible ground-water contamination from a landfill during preliminary work for highway construction. The landfill was in an abandoned limestone quarry. At first all types of refuse went into the site, with disposal into several feet of water in the quarry. Later, only demolition wastes were accepted. An investigation revealed ground-water contamination and traced it to the landfill operation.
Geologic setting: The landfill is situated in an abandoned limestone quarry, which was about half full of water. Ground water is unconfined.
Remedial action and effectiveness: The site was excavated and dewatered for freeway construction. The water removed by dewatering was chlorinated and discharged to surface water.
Reference 70.

CASE HISTORY 107

Location: Woodbury Township, Minnesota.
Contaminant: Spent solvents and acids.
Source of contamination: Impoundments.
Effect on the environment: One private well was found to be contaminated.
Background: From the mid-fifties until 1966, a company used pits for disposal of spent solvents and acids. A 1963 investigation by the Minnesota Water Pollution Control Commission indicated the possibility of ground-water contamination. The report recommended that disposal of acids be stopped and all other wastes go to clay-lined impoundments. These two recommendations were followed, but in 1966, one of the near-by private wells showed ground-water contamination.
Geologic setting: Glacial drift is present at the surface. No other information was given.
Remedial action and effectiveness: All use of the disposal site was stopped. A 200-foot test well was drilled, and most ground-water contamination was found near the surface. The 200-foot well was converted to a barrier well to prevent the spread of ground-water contamination. Pumping at 700 gallons per minute began January 1968. Two additional barrier wells have since been constructed and put in operation. Pumping continues, but contamination is still present.
Reference 70.

CASE HISTORY 108

Location: Villages of Roseville and Lauderdale, Minnesota.
Contaminant: Gasoline.
Source of contamination: Unknown.
Effect on the environment: One municipal well and several private wells were affected. The extent of ground-water contamination is continuing to grow; at the time this was written, gasoline had moved with ground water about 2 miles from the suspected source.
Background: About 1957, several private wells showed signs of gasoline contamination. About a year later a municipal well was affected. No specific source was located, but it is believed that an accidental discharge of gasoline took place prior to 1950 near large gasoline storage facilities. The private wells are about a mile and the municipal well 2 miles south of the suspected source.
Geologic setting: Ground-water movement is to the south.
Remedial action and effectiveness: The municipal well was abandoned and the village was hooked up with water from the city of St. Paul.
Reference 70.

CASE HISTORY 109

Location: Minnesota.
Contaminant: Chlorides.
Source of contamination: Salt storage area.
Effect on the environment: A private well was contaminated. The extent of ground-water contamination was not mentioned.
Background: When a private well became contaminated, chemical tests of the well water showed 2700 mg/l of sodium chloride. The contamination was traced to a storage area for road salt near the affected well.
Geologic setting: No information given.
Remedial action and effectiveness: The salt pile was removed. Other corrective action was reported to be under consideration.
Reference 70.

CASE HISTORY 110

Location: Pine Bend, Minnesota.
Contaminant: Industrial wastes—acids, oils, and fertilizer wastes.
Source of contamination: Improper disposal of waste.
Effect on the environment: Ground water was contaminated.
Background: The Minnesota Pollution Control Agency made a survey in 1971 of surface and ground water in the vicinity of three industrial plants. The results showed ground-water contamination as a result of operations of all three plants.
Geologic setting: Glacial drift in the vicinity of the three industries is 50 to 100 feet thick. Underlying the surficial material is the Prairie du Chien Dolomite and the Jordan Sandstone. The bedrock aquifer is believed to be unconfined.
Remedial action and effectiveness: All three companies agreed to stipulations for adequate treatment of all wastes. No efforts to clean up the ground water were mentioned.
Reference 70.

CASE HISTORY 111

Location: St. Louis Park, Minnesota.
Contaminant: Creosote and petroleum products.
Source of contamination: Improper disposal of waste.
Effect on the environment: One municipal well and several private wells were contaminated in a shallow, unconfined aquifer.
Background: In 1932, a St. Louis Park municipal well was abandoned because of the taste of the water. Several shallow, private wells were contaminated about the same time. An investigation in 1935 concluded that ground-water contamination was a result of operations of two companies. One company distilled coal tars to obtain creosote oil that the other company used to impregnate wood products. During the 50 years of operation, much of the site had become saturated with creosote and petroleum products. Because a deeper aquifer was present as an alternative water supply, no action was immediately taken; people accepted the situation. Concern in recent years about possible contamination of the deeper aquifer prompted legal action by the Minnesota Pollution Control Agency. The companies then decided to go out of business.
Geologic setting: No geologic information was provided. However, two aquifers are present. Apparently only the shallow unconfined aquifer and wells in that aquifer have thus far been affected.
Remedial action and effectiveness: Some clean-up action was to be required of the two companies.
Reference 70.

CASE HISTORY 112

Location: West Virginia, Monroe County, near Union.
Contaminant: Chlorides.
Source of contamination: Salt storage area.
Effect on the environment: Several wells were contaminated.
Background: Chloride concentrations rose steadily in several shallow wells for about 4 years when a storage area for road salt was installed near by. Concentrations of chlorides as high as 7200 mg/l were recorded.
Geologic setting: The area is underlain by a highly permeable carbonate aquifer. The affected wells were finished in this aquifer about 1500 feet down-gradient from the salt storage area.
Remedial action and effectiveness: The salt pile was removed and stored in a protective building in late 1970. Within two months, chloride concentrations in the wells dropped to acceptable levels.
Reference 72.

CASE HISTORY 113

Location: West Virginia, Grant County.
Contaminant: Chlorides.

Source of contamination: Land disposal of wastes.
Effect on the environment: A well became contaminated.
Background: Contamination of a well was traced to the land disposal of waste water from a zeolite water softener. Concentrations of chlorides increased to 1712 mg/l before disposal was stopped.
Geologic setting: The well, 160 feet deep, obtained water from a shale aquifer. No other geologic information was given.
Remedial action and effectiveness: None reported. However, shutdown of the dumping operation for several months in early 1970 caused a slowdown in the rate of increase of chloride. Between January 1971 and May 1971, chloride concentrations dropped from 1712 to 1650 mg/l.
Reference 72.

CASE HISTORY 114

Location: Near Wausaw, Wisconsin.
Contaminant: Paper-mill wastes.
Source of contamination: Impoundment.
Effect on the environment: An industrial well became contaminated.
Background: An industrial well pumping 500 gallons per minute became contaminated. The contamination was traced to an infiltration pond containing paper-mill wastes across the Wisconsin River from the well.
Geologic setting: The site is underlain by an unconfined sand and gravel aquifer 100 to 130 feet thick. The water table is at a depth of 5 to 25 feet. Ground-water movement near the pond is eastward, toward the Wisconsin River about 350 feet away. However, some contaminated ground water apparently moved beneath the river to the affected well some 600 feet east of the river. The cone of depression for the industrial well appears to reach the river.
Remedial action and effectiveness: No remedial action was reported.
Reference 73.

CASE HISTORY 115

Location: Southern New Jersey.
Contaminant: Industrial waste—hexavalent chromium.
Source of contamination: Impoundment.
Effect on the environment: The zone of ground-water contamination extends 3000 feet from the source.
Background: No mention is made as to how the problem was detected. The source of ground-water contamination is an unlined lagoon that received chromium-laden process water. The waste water had been discharged to the pond for 14 years.
Geologic setting: Unconsolidated Coastal Plain sediments underlie the site. No ground-water information was provided.
Remedial action and effectiveness: An intensive drilling and sampling program was undertaken to define the extent of contamination. One well was drilled to 120 feet and sampled at 20-foot intervals. Five wells were drilled in a cluster at 20- , 40- , 60- , 80-, and 100-foot depths, and samples were taken to compare with those from the 120-foot well. Information was obtained on vertical and horizontal distribution of the contaminant. According to reports, a program of ground-water recovery and treatment was to be developed.
Reference 74.

CASE HISTORY 116

Location: Anchorage, Alaska.
Contaminant: Leachate.
Source of contamination: Greater Anchorage Area Borough Landfill.
Effect on the environment: Ground water of the shallow aquifer showed some contamination.
Background: An investigation of possible ground-water contamination from a landfill was begun in 1973. Landfilling began in 1958, and the disposal area has included two lakes. This investigation showed that the surficial aquifer has been contaminated but that the contamination does not extend far beyond the boundary of the landfill.
Geologic setting: The landfill is located within a muskeg and lake complex in the western part of the Anchorage glacial plain. The surface material consists of 1 to 6 feet of moist to saturated peat. It is underlain by layers of gravel, sand, silt, and clay. With increasing depth, the beds become finer grained and less permeable. The static water level of the unconfined surficial aquifer is 10 feet or less from the surface. The ground-water gradient is nearly flat, sloping to the west. At depth there is a confined aquifer that serves as a major source of public water. It was not reported to be contaminated.
Remedial action and effectiveness: None reported.
Reference 75.

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Leachate	see	Landfill
Mine wastes	see	Impoundment, improper waste disposal
Organic wastes	see	Impoundment, septic tank, feed lot, improper waste disposal
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